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Water and Energy Commission Secretariat
Singha Durbar, Kathmandu
Nepal

Final Report

(Karnali 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 $2/3^{rd}$ of global CO_2 emissions 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 regional energy crises, energy production from renewables is leaping 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. Energy sector accounts for primary reason of the polluted air that more than 90% of the global population are 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 recent Energy Synopsis Report of Nepal, Nepal's final energy consumption stands at 640 PJ in 2022, out 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 99% HHs 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 UNFCC in 2021 before COP26 and the Nepal Government has reemphasized the pledge recently 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 consumption 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 were 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 consumption 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, 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 include the name and contact number of the concerned person of the concerned institution and was submitted to WECS after completion of the field work in Field/Interim report.

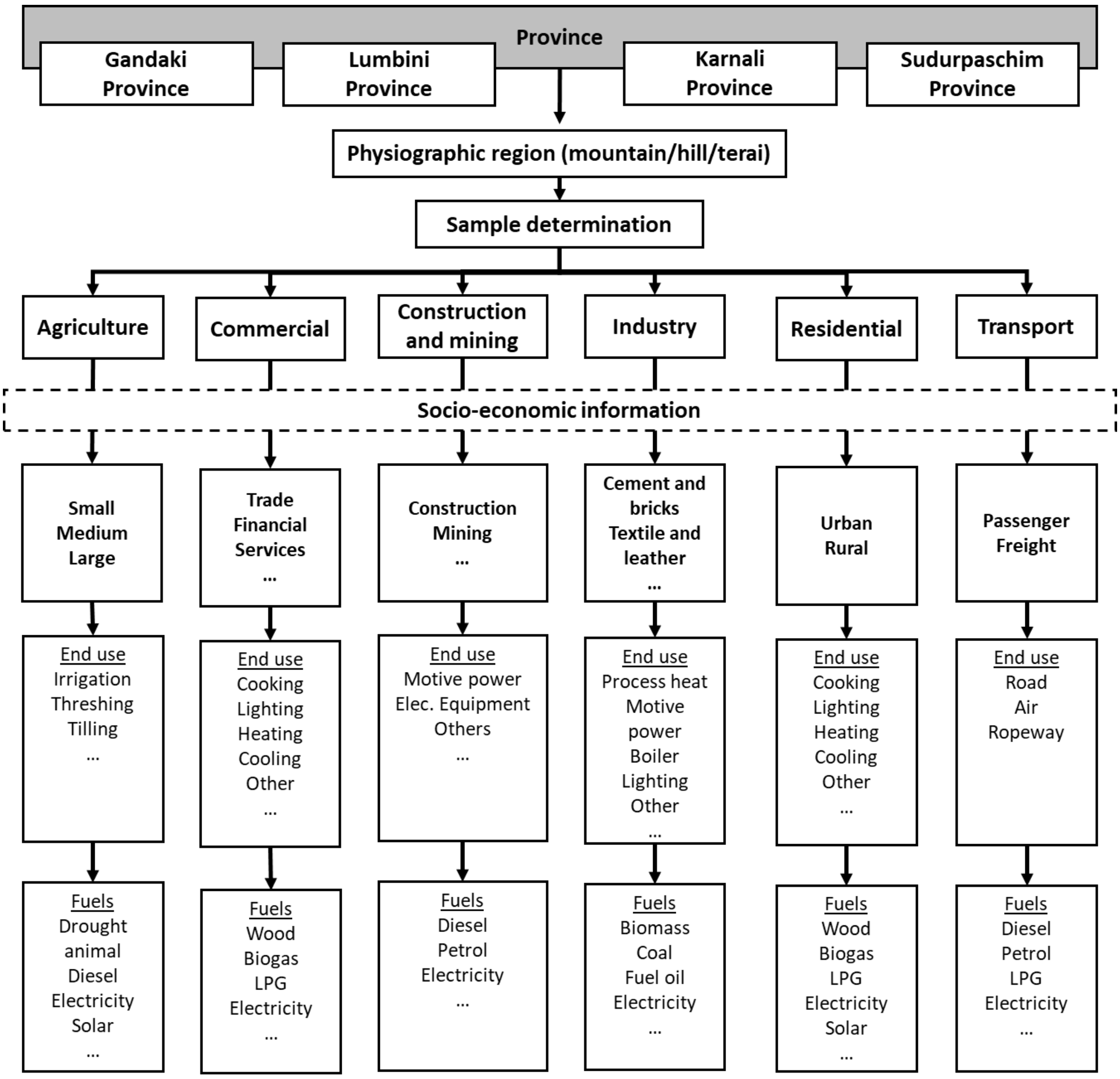
Karnali Province

The total area of the province is 27,984 square kilometers covering 18.97% of the nation's geographical area, which makes Karnali Province the largest province by far. According to the 2021 census, the population of the province was 1.69 million making it the least populous province (NSO, 2023). It borders the Tibetan Autonomous Region of China to the north, Gandaki Province to the east, Sudurpashchim Province to the west, and Lumbini Province to the south. Birendranagar with a population of 47,914 is both the province's capital and the largest city. Karnali Province is administratively divided into 10 districts, 25 municipalities, and 54 rural municipalities. Birendranagar is a major trade and commercial center in the mid-western region and is the provincial capital. It is the only city in the province with a population of over 50,000 people.

Methodology for Study

The methodological approach as conducted systematically identifying the steps in collection, analysis, and synthesis of information from different sources. 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 1 for Karnali 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 Karnali 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 was considered at the end-use level for each sector. The base year was taken as 2022 for energy consumption analysis. From here, energy scenarios have been developed until 2050, and 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, Model for Analysis of Energy Demand (MAED) is used for energy demand projection. Secondly TIMES model has been used, that includes demand projection as well as the supply and emission analysis.

Energy Supply Situation in Karnali Province

Solid Biomass Energy

Karnali Province of Nepal is blessed by nature with lush forests in 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 Karnali and its provincial territories, and abundant alluvial soil. Although deforested to some level, there is still good forest cover throughout the province. But urbanization and agriculture have encroached on good forest lands which are prominent, especially in the Surkhet district. Similarly, human pressure for fuelwood in the past has led to deforestation. Despite this, Karnali Province has good potential for forest management and production with its rich soil and history of community forestry. But rampant poverty in districts like Kalikot makes the people overly reliant on cheap bioenergy. annual fuelwood from the whole Karnali Province is 3,390,229 m^3 (This is the approximate harvestable quantity) corresponding to 2.4 million tons of fuelwood per year. Animal dung potential is 3.47 million t per year. Biogas potential is around 1,710 TJ. There is an approximate potential of 15,382 TJ of agriculture waste/residue in Karnali Province.

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 Karnali Province (NOC)

Districts	MS	HSD	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Dailekh	303	2,798	-	-	-
Jumla	91	864	-	-	-
Kalikot	-	550	-	-	-
Salyan	1,159	5,089	-	-	-
Surkhet	7,432	24,273	445	1,491	-
Western Rukum	397	1,781	-	-	-
Total	**9,382**	**35,355**	**445**	**1,491**	**-**

(NOC, 2022)

LPG sales could not be 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

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. 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. Karnali Province has hydropower potential of 13,702 MW which is 19% of the Nepal’s potential as per WECS’s river basin report (WECS, 2019). As per NEA 2080 distribution report, Karnali Province has the lowest electricity access to households at 66% but it has current hydropower production of 565 MW. In 2022 sales contribution is 0.79% of the total NEA sales at 60.7 GWh. Karnali has the highest distribution loss at 16%. Energy and economic poverty in Karnali are the highest among the provinces (NEA,2022).

Modern Renewables

There are 5 MW of micro-hydro projects, 211, 000 SHS and 1 MW of institutional solar photovoltaic systems installed in Karnali Province. There are 6,000 domestic biogas plants, 80,000 mud ICS and 11,000 metallic ICS installed in the province (AEPC, 2021).

Energy Consumption in 2022

The total final energy consumption (FEC) in Karnali Province was found to be 19,594 TJ in 2022. The abundance of indigenous resources mainly fuelwood available in the province could be seen as the share of biomass is comparatively high with 87% of total consumption in the province. In this province, 82% of households still use fuelwood stoves, only 17% of households owns LPG and just 0.1% of households use electricity for cooking. Figure 1 and Figure 2 show the energy consumption as per fuel mix and consumption in different economic sectors.

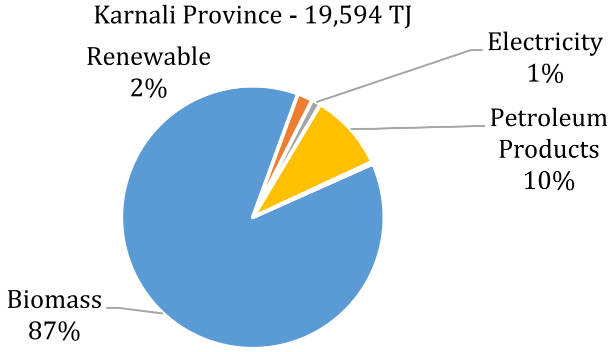


Figure 1. Energy Consumption Share in Karnali Province by Energy Types

The residential sector is the highest energy-consuming sector, and the use of biomass is prevalent in its energy mix. The commercial sector is second at 5% followed by the transport sector at 4%. Since there are limited industries operating in the province, industrial energy consumption is at 2%. Although mechanization in the agricultural sector is gaining popularity, the use of fuel in this sector is very low at 1%.

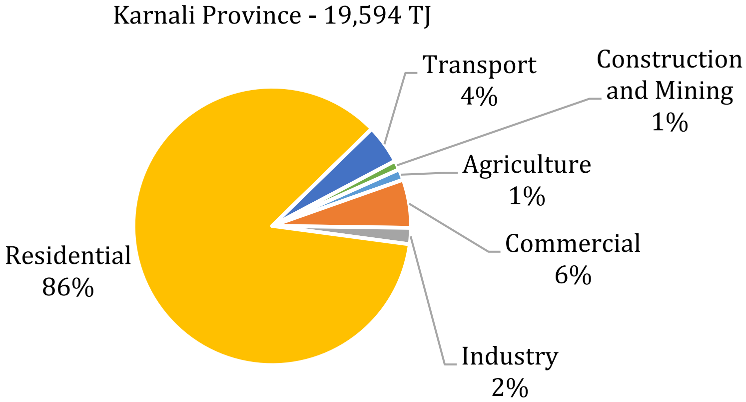


Figure 2. Energy Consumption by Sectors in Karnali Province

Energy consumption indicators which highlight the status of energy consumption in Karnali Province, show the total final energy consumption per capita is 12 GJ, which is lower than the national average. Per capita electricity consumption comes out to be 96 kWh and electricity consumption per household is 109 kWh, which lies in tier 2 of the World Bank's multi-tier framework. Electricity consumption should be around the tier-5 level of 3,000 kWh per household in a developing country by 2030.

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 and a very small portion of energy are utilized in economic activities.

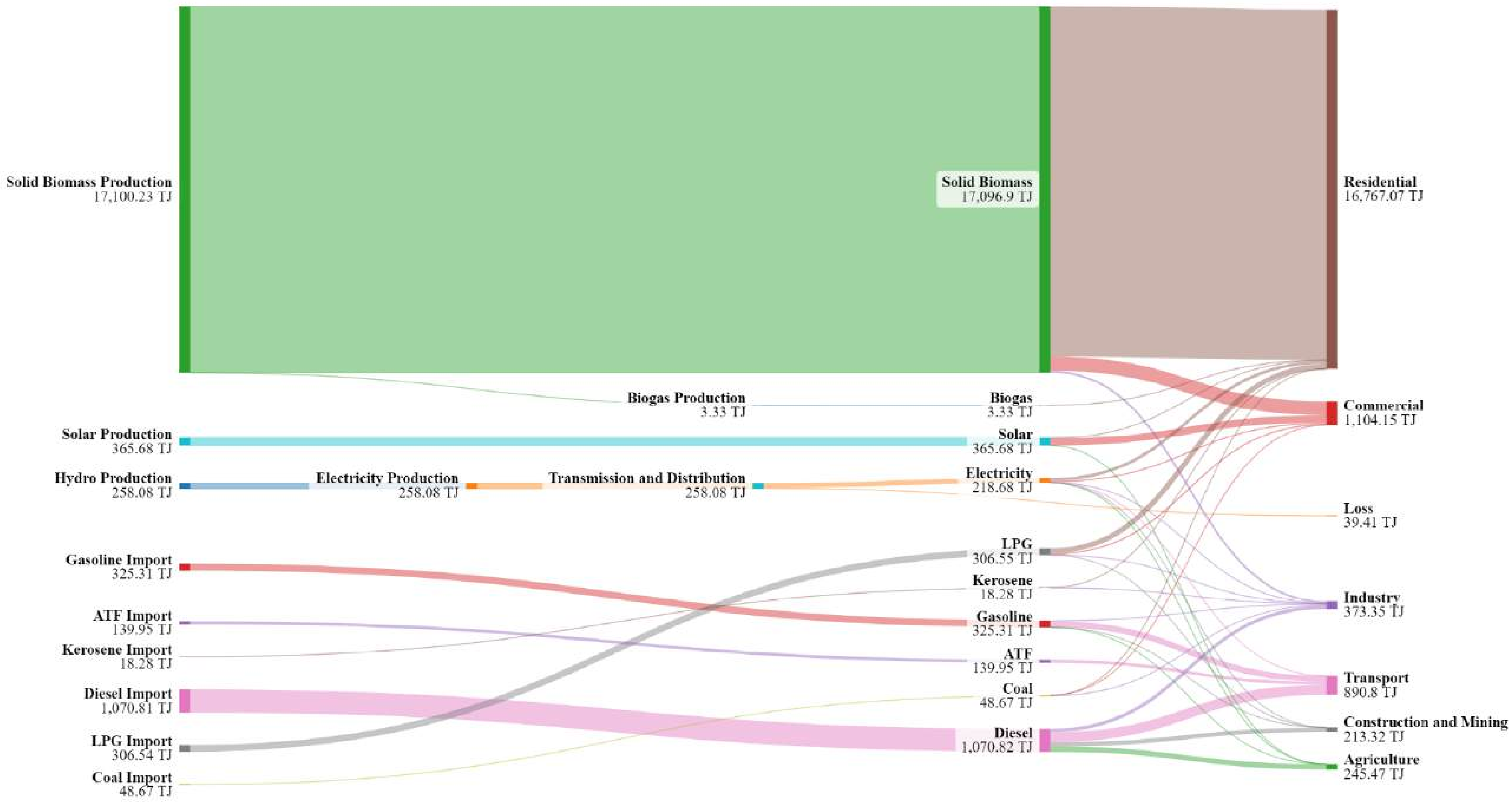


Figure 3. Sankey Diagram for Flow of Energy in Karnali Province

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. A comparative analysis of REF and SED scenarios in Karnali Province is also conducted. In the REF scenario, energy consumption reaches 20 PJ in 2030 and 28 PJ in 2050 respectively. In the SED scenario, the energy consumption attains 10 PJ in 2030 and is expected to be 15 PJ in 2050 respectively.

Comparison between SED and REF scenarios indicates that per capita electricity in Karnali Province reaches 929 kWh in 2050 in the SED scenario compared to 446 kWh in the REF scenario. Per capita GHG emissions decline to 142kg in 2050 in the SED scenario, whereas it will be 301 kg in the REF scenario. Installed power plant capacity reaches 606 MW in 2050 in the SED scenario. But it will be 148 MW in the REF scenario. Electricity demand projection looks very low as there are very few industries and economic activities are also limited in the province.

Figure 4 indicates that in the absence of initiatives to promote clean and renewable energy, Karnali Province will persist in its substantial dependence on biomass energy sources and an escalating reliance on imported petroleum products. This will lead to a notable surge in the demand for fossil fuels by the year 2050. The sustainability of such a significant demand for biomass energy sourced from the region's forests raises considerable doubts. Furthermore, there are valid concerns about whether Karnali Province's economy can viably sustain the long-term imports of such extensive quantities of fossil fuels.

The Sankey diagram in Figure 5 demonstrates a shift away from heavy dependence on solid biomass to fulfill energy needs, with electricity taking its place according to the SED Scenario projections by 2050. This transformation in Nepal's energy sector indicates that a significant portion of electricity generation in the Karnali Province will come from clean and renewable sources. This change not only enhances energy security but also contributes to sustainability in the region.

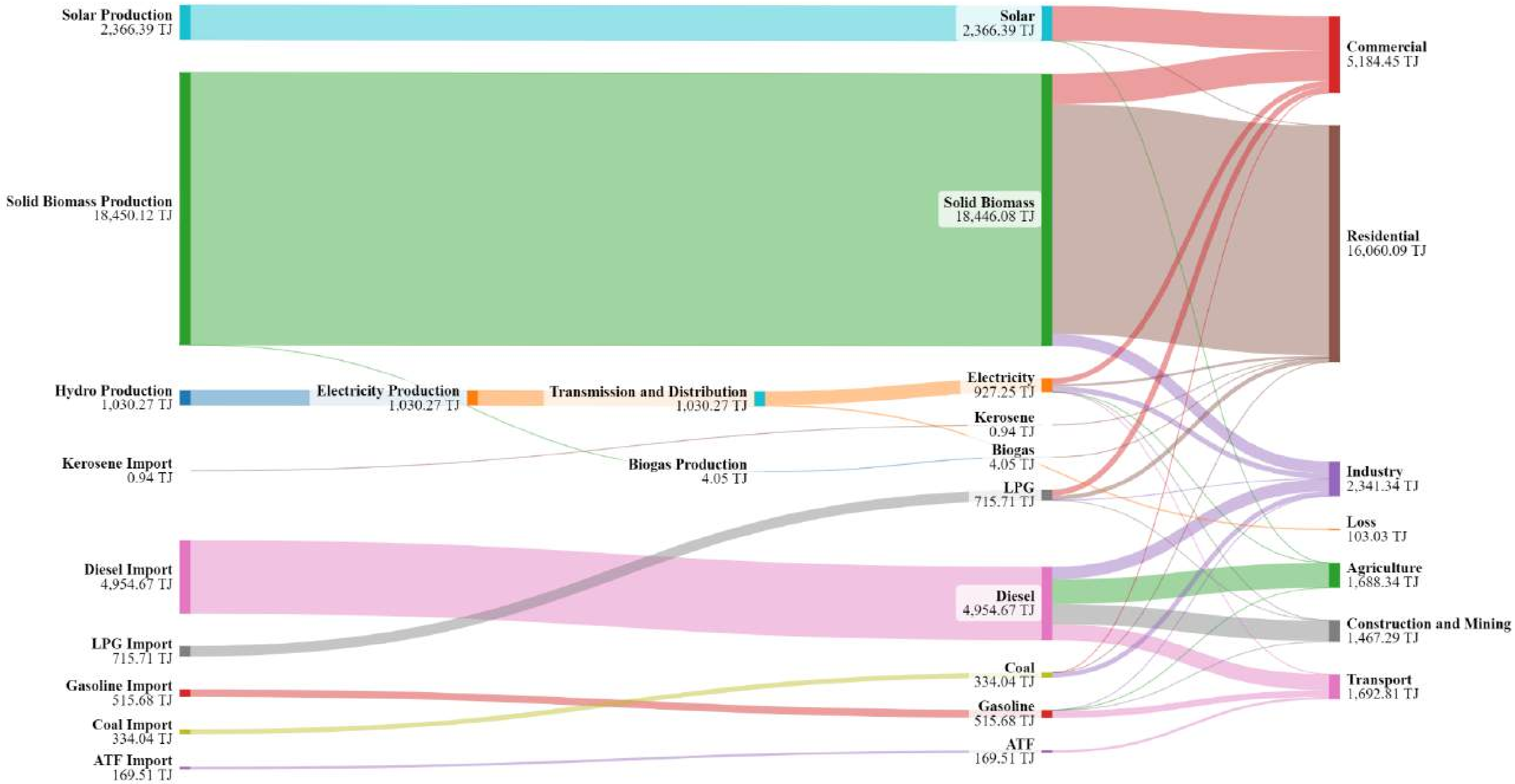


Figure 4 Sankey Diagram for Flow of Energy in Karnali Province for the Reference Economic Growth Scenario in 2050

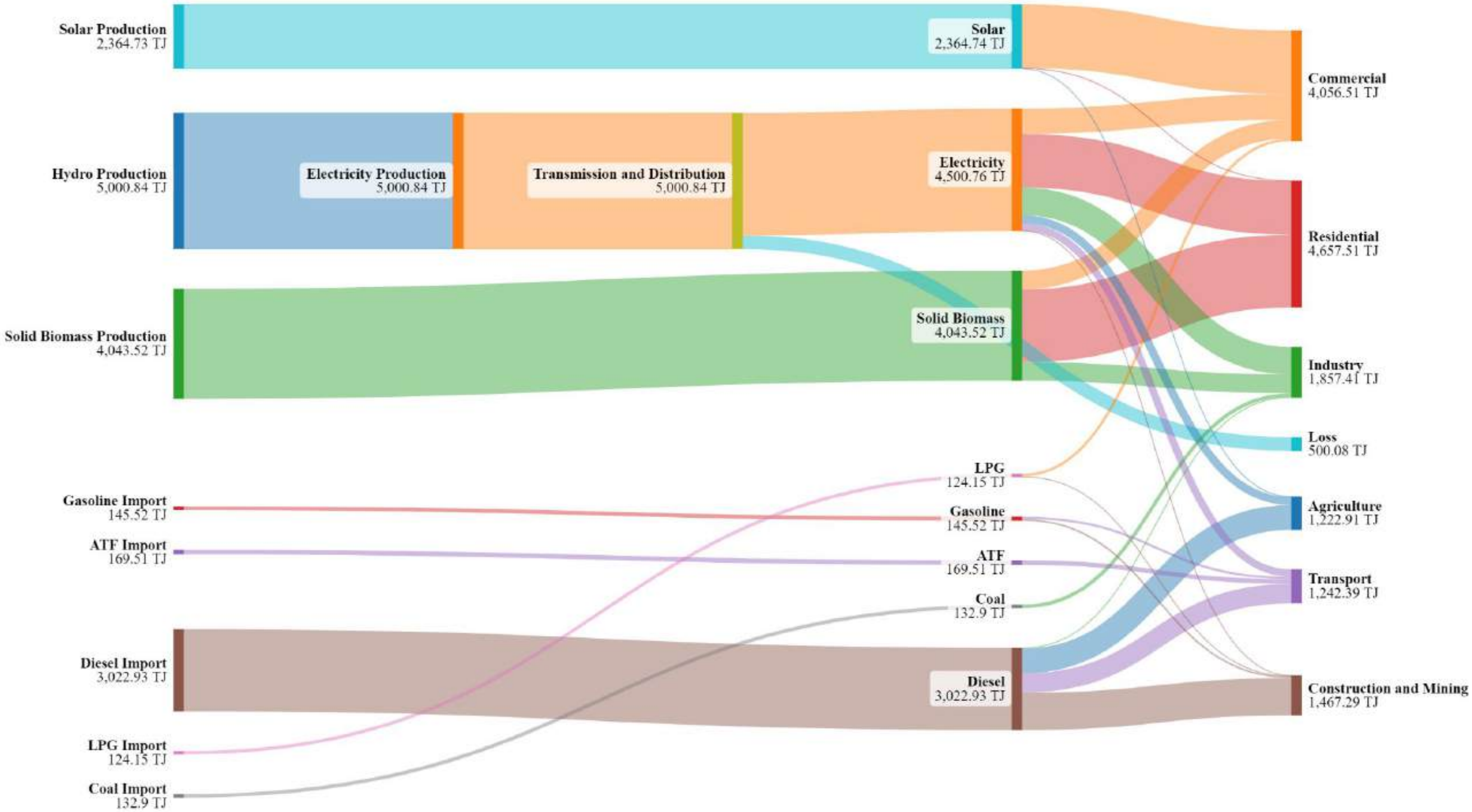


Figure 5 Sankey diagram for flow of energy in Karnali Province for the Sustainable Energy Development Scenario in 2050

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Karnali 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. As energy and economic poverty are rampant in the province, federal and the provincial governments must focus on additional efforts for the energy transition to clean energy in Karnali Province. This study also indicates that with the core focus on energy security, reliability, and sustainability, Karnali 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 Global Outlook

Global energy sector has been moving towards renewable energy at faster pace than ever. After the COVID - 19 pandemic and regional energy crises, energy production from renewables is leaping 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. The report also suggests that the speed of change in energy can be countered by 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 with the crisis in Ukraine from February 2022 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 depend on the import of electricity from neighbors in the dry season are in a very precarious situation since most of the power plants in India and other countries are based on fossil fuels. These events forebode a catastrophic future in the world and emphasize the need to rapidly transition 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. 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. The countries must act to provide modern energy services, which is a necessity for eradicating poverty and reducing the divide between the rich and the poor. Besides, several empirical studies have shown that non-renewable energy is a major source of air pollution that causes severe health problems globally, especially in developing countries like Nepal. The energy sector is responsible for almost three-quarters of the emissions. Hence, it is of utmost importance to implement solutions to climate change. Energy features are prominent 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 by 2030 with a vibrant, youthful middle-class population. 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 (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 required 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 in place for the whole energy system both at the local and provincial levels. These need to be later integrated into the national energy systems planning for sustainable energy development and energy security in the country.

1.2 Background

Energy is an essential requirement for the economy and the sustenance of the people in any country. Developments in society and energy systems have a strong correlation in effect and influence. The most meaningful transformative change in creating a precursor to our present energy systems happened during the Industrial Revolution in England circa 1750. 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 – extensively used in cooking and heating. However, around 1900, two major developments occurred – the introduction of electricity supply through electricity grids and power plants fired by coal, oil, and based on hydropower (Blok et al., 2021). The adverse impacts of climate change have become severe leading to a strong global

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

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

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 Water & Energy Commission Secretariat (WECS) is 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/Consumption Profiles at the regional level and Residential Energy Supply/Consumption Profiles at the district level during 1990-1995. Regional and district-level sectoral energy supply-consumption 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 last national energy survey carried out by WECS.

With Nepal transitioning into a federal system, it 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 demands 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 demand of the remaining four provinces viz – Gandaki, Lumbini, Karnali, and Sudurpashchim Provinces. This study pertains to the energy consumption and supply situation of the Karnali 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 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.

1.3 National Energy Scenario

The national energy consumption has been seeing growth along with growth in population and economy –a common feature of a developing country. However, Nepal’s overall energy mix is 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 recent Energy Synopsis Report of Nepal, Nepal’s final energy consumption stands at 640 PJ in 2022, out of which tradition biomass occupies 64%, commercial energy carriers occupy 28%, grid electricity 5% and renewables around 2.5% respectively (WECS, 2023). Nonetheless, it is important to note that there is an evident shift in commercial fuels – primarily petroleum products. The recent provincial energy consumption and supply situation analysis completed for Koshi Province and Madhesh and Bagmati Province by WECS in 2020 and 2022 supports also the transition in energy mix patterns by sectors.

Nepal besides the gradual energy transition 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 with 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 as cooking on electricity rather than on LPG and fuelwood. Analysis of household energy economics in urban areas indicate 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. Hydroelectricity 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 and 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 its Long-Term Strategy for net-zero emissions by 2045 follow the Paris Agreement of 2015, the SDG7 and other goals, and the SE4ALL program. SE4ALL 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, primarily 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 access to electricity in Nepal (Adhikari, 2019; NEA, 2019). By the end of the fiscal year 2021/22, it is expected to be at 7% only who do not have access to electricity (MoF, 2022). Solar home systems are taking a strong foothold in Nepal with the reduction of their global price per unit as well as their quick availability. 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 consumption, 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 in Nepal

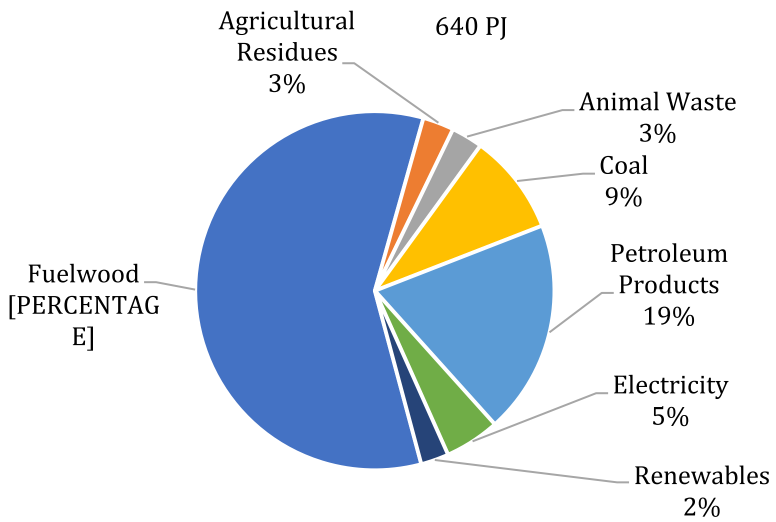
The overall energy consumption in Nepal reveals the dominance of the use of non-commercial energy sources. The total energy consumption of Nepal in 2022 stood at 640 PJ with an annual average growth rate of 2.3% YOY. As per the energy synopsis report published by WECS, traditional energy consumption 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 31% 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. Meanwhile, the consumption of electricity has also lately increased to 5% from 2% a decade ago. The energy consumption by fuel type in 2021/22 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 the dominating 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 Total 84 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. Fuel wise, 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 sources of energy in the residential sector are 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 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. Nepal's roadmap for 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 15,000 MW 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 electric technologies have significantly increased the consumption for electricity in the last 2 years (NEA, 2022).



(WECS 2023)

Figure 1-1. Energy Consumption by Fuel Type in 2021/22 in Nepal

[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.

1.5 Provincial Situation

1.5.1 Karnali Province

The total area of the province is 27,984 square kilometers covering 18.97% of the nation's geographical area, which makes Karnali Province the largest province by far. According to the 2021 census, the population of the province was 1.69 million making it the least populous province (NSO, 2023). It borders the Tibetan Autonomous Region of China to the north, Gandaki Province to the east, Sudurpashchim Province to the west, and Lumbini Province to the south. Birendranagar with a population of 47,914 is both the province's capital and the largest city.

The province has a large proportion of land located in the high mountainous region with rugged topography with low to very low agricultural potential. It contains KubiGangri, Changla, and Kanjiroba mountains in the north. The Shey Phoksundo National Park with the Phoksundo Lake is the largest national park in Nepal. Karnali Province also houses the Rara Lake, the largest lake in Nepal and a major tourism destination. Karnali River is the largest river system in the country with Bheri and Seti as its major tributaries. The province has the highest hydropower generation potential in the country, but this potential is yet to be realized.

Karnali Province is administratively divided into 10 districts, 25 municipalities, and 54 rural municipalities. Birendranagar is a major trade and commercial center in the mid-western region and is the provincial capital. It is the only city in the province with a population of over 50,000 people.

The GDP growth rate of Karnali Province in 2018/19 before Covid-19 was 8.4% but it was reduced to 1.4% in FY 2019/20 due to its aftermath. It is worth mentioning that the growth rate of all provinces in that year was negative except for Karnali and Sudurpashchim Provinces. In the case of Karnali and Sudurpashchim Provinces, it may be due to slow economic development and low participation in foreign trade. The estimated GDP Growth rate of Karnali Province in FY 2021/22 had reached 5.5% only, which was still less than that of the pre-Covid-19 year, whereas the economic growth rate of the country was estimated to be 5.8% (MoF 2022) **(Figure 1-2)**.

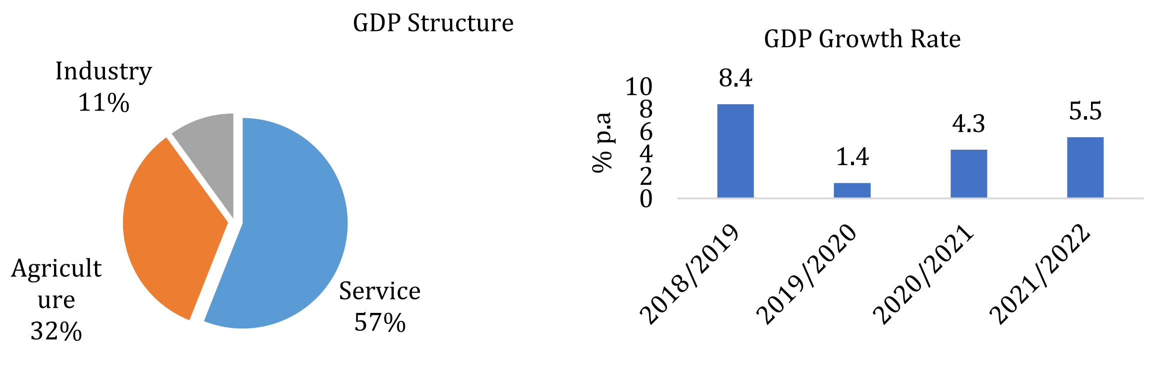


Figure 1-2. Economic Status of Karnali Province

Of the estimated GDP (at producer's price) of Rs. 4,266.32 billion in FY 2020/21, the share of Karnali Province to the national GDP was the lowest at 4.1 percent, whereas that of Bagmati Province was the highest at 37 percent. The share in the GDP of Bagmati Province increased whereas the share in GDP of Karnali Province marginally decreased in FY 2020/21 compared with that of the previous fiscal year 2019/20.

The composition of provisional GDP in the FY 2020/21 shows that the contributions from the agriculture, industry, and services sectors were 32%, 11%, and 57% respectively. The major contributing sector to GDP was the services sector as with other provinces. The agriculture and forest sectors are the lifeblood of the economy, providing a source of revenue for three-fourths of the population.

Of the total provincial expenditures in the three consecutive fiscal years 2017/18, 2018/19, and 2019/20 (Rs. 2,362 million, Rs. 112,090 million, and Rs. 156,114 million), the weightage expenditures in these consecutive years were the highest in Koshi Province. Karnali measured the least weights of 0.10, 0.09, and 0.11 in these three fiscal years 2017/18, 2018/19, and 2019/20 respectively. Data indicates that the utilization of fiscal resources in this province was very poor.

In the fiscal year 2019/20, the percentage of actual expenditure to the total appropriated budget was high in Lumbini (69.8%) and Gandaki (63.5%) provinces whereas the percentage of actual expenditure was relatively low in Province 2 (46.5%) and Karnali Province (38.3%). The Karnali provincial government failed to channel the funds sufficiently and efficiently for developing activities. During the period 54.6 percent of the total appropriation was spent on an average of all the provinces.

The ratio of capital expenditure to total expenditure in Karnali Province in 2020/21 was 45.8% against 50.1% in the country. It was 56.5% in 2019/20 and 54.1% in 2018/19.

The total revenue collected by local levels was Rs. 183,889.6 million. But local levels in Karnali Province had collected only 9.0%, which was the least. As much as 66% of the population has access to electricity in the province (NEA, 2023). Karnali Province generates only 11 MW of hydroelectricity (MoF, 2022). According to the NEA, the highest sales of electricity sale is to the domestic sector (50%) followed by the commercial sector (20%). The loss of electricity in the province was estimated at 16.20% for the year 2079/80.

Taking the administrative and population situations into consideration, Karnali Province covers 21.6% of the total area with 79 local levels and 5.81% of the total population. Forests cover 17.9% of the total land area of the country. The local road network in this province has extended now to 3,301 km (5.1% of the national total road length). The total number of schools in Karnali is 3,112 (9.1% of the 4 total). 2.6% of the total hydropower (i.e., 52MW) was produced and Rs. 135.2 billion has been invested in 29,248 industries in the province. The provincial economic and social indicators of Karnali Province are as shown in **Table 1-1.**

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

Indicators	Nepal	Karnali	Share (%)
Administrative and population situation[1]			
No. of local level	753	79	10.5
Population (%)	100	5.81	5.8
Area (%)	100	21.6	21.6
Economic and Social Sectors			
Economic growth at consumers' prices (%)[1]	5.84	5.47	93.7
Gross Domestic Production			
Provincial contribution to GVA (at consumers' prices)	100	4.1	4.1
Per capita GDP (in US $)[1]	1,372	964	70.3
No. of registered industries[2]	8,656	79	0.9
No. of cottage and small industries[2]	555,776	29,248	5.3
Investment in industry (in Rs. billion)[2]	2,512.1	135.2	5.4
No. of registered companies[3]	283,358	3,526	1.2
hydropower production (MW)[4]	2,023	565	2.6
Forest Area (%)[5]	100	17.9	17.9
Local road network (KM)[6]	64,617	3,301	5.1
No. of Schools[7]	34,368	3,112	9.1
Financial sector[8]			
No. of branches of bank and financial institutions	11,349	451	0.4
Population per branch (no.)	2,572	3,758	146.1
Branch of Insurance companies (No.)[9]	2,905	187	6.4
provincial expenditure (in Rs. 10 million)[10]	18,883	2,204	11.7
provincial revenue (in Rs. 10 million)[10]	8,794	767	8.7

Sources: 1. Central Bureau of Statistics, 2022,2. Ministry of Industry, Commerce and Supplies, 2022,3. Company Registrar's office, 2022, 4. Ministry of Energy, Water Resources, 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.

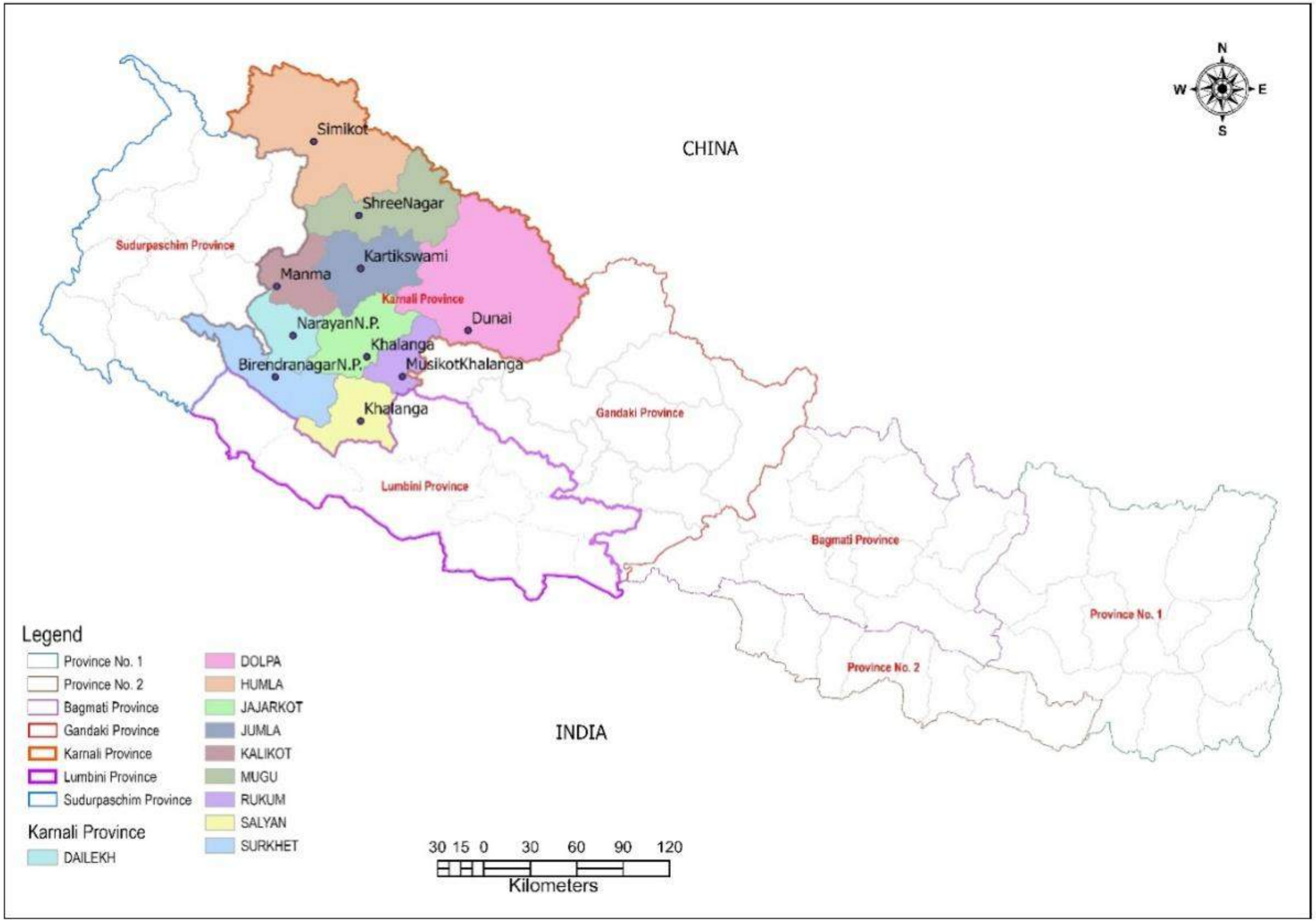


Figure 1-3. Karnali Province

AEPC has been able to implement 1,851 nos. of mini and micro hydro projects generating 34.47 MW of electricity in 2021. Among these, 186 nos. of projects are implemented in Karnali Province generating 4.96 MW of electricity benefiting 12,907 nos. of rural households. Western Rukum has comparatively more beneficiary households covering 26.29% of total provincial beneficiaries while Salyan had the least number with only 0.52% coverage. According to the AEPC, 2,253 nos. of improved water mills, 211,011 nos. of solar home system units, 697 nos. of institutional solar PV System generating 1053.9kWp, 14 solar irrigation systems, and 33 solar water pumping systems has been installed which covers 19.7%, 26.5%, 19.6%, 0.6%, and 17.6% of the total country installation respectively.

AEPC to address the need for modern renewable energy, cleaner cooking technology, household air pollution reduction, and to improve the health conditions of the rural population, 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, only 6% of the installation has been done in Karnali Province, i.e., 5,754 Nos. of domestic biogas plants, 80,254 mud ICS and 10,865 metallic ICS (AEPC, 2021)

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

1.6.1 Policy and Strategy Overview

The GoN has recently taken back the Electricity Bill -2077 under consideration at the National Assembly[4]. The government is in the process to revise 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 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.

- **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.

[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

- **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 mitigation 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, 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
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

Key Plans, Policies, programs	Features
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.
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[6]. The government is in the process of revising the law to allow the private sector in

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

the power trade through an amendment to the Electricity Act[7]. There is huge pressure from the private 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 polices related to energy aid the production of renewable energy and sets targets for development in energy sector, mainly in hydropower, solar and clean energy. It is imminent that demand for commercial energy would grow nationally as well as in provinces as well. Therefore, in this context, in accordance with the current policies and targets set by the government, the study team has looked upon 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.

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

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.**

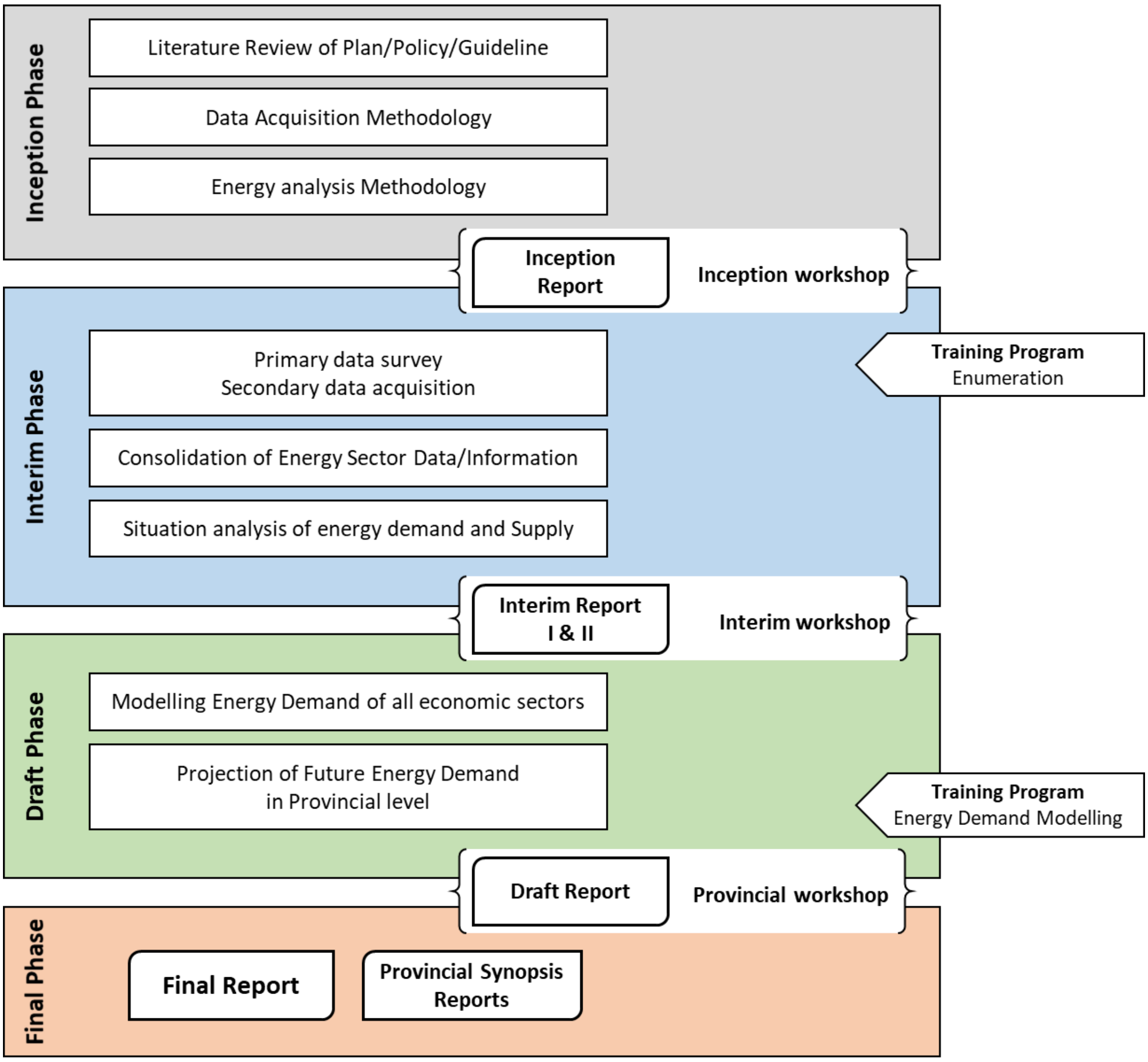


Figure 2-1. Methodological Framework

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

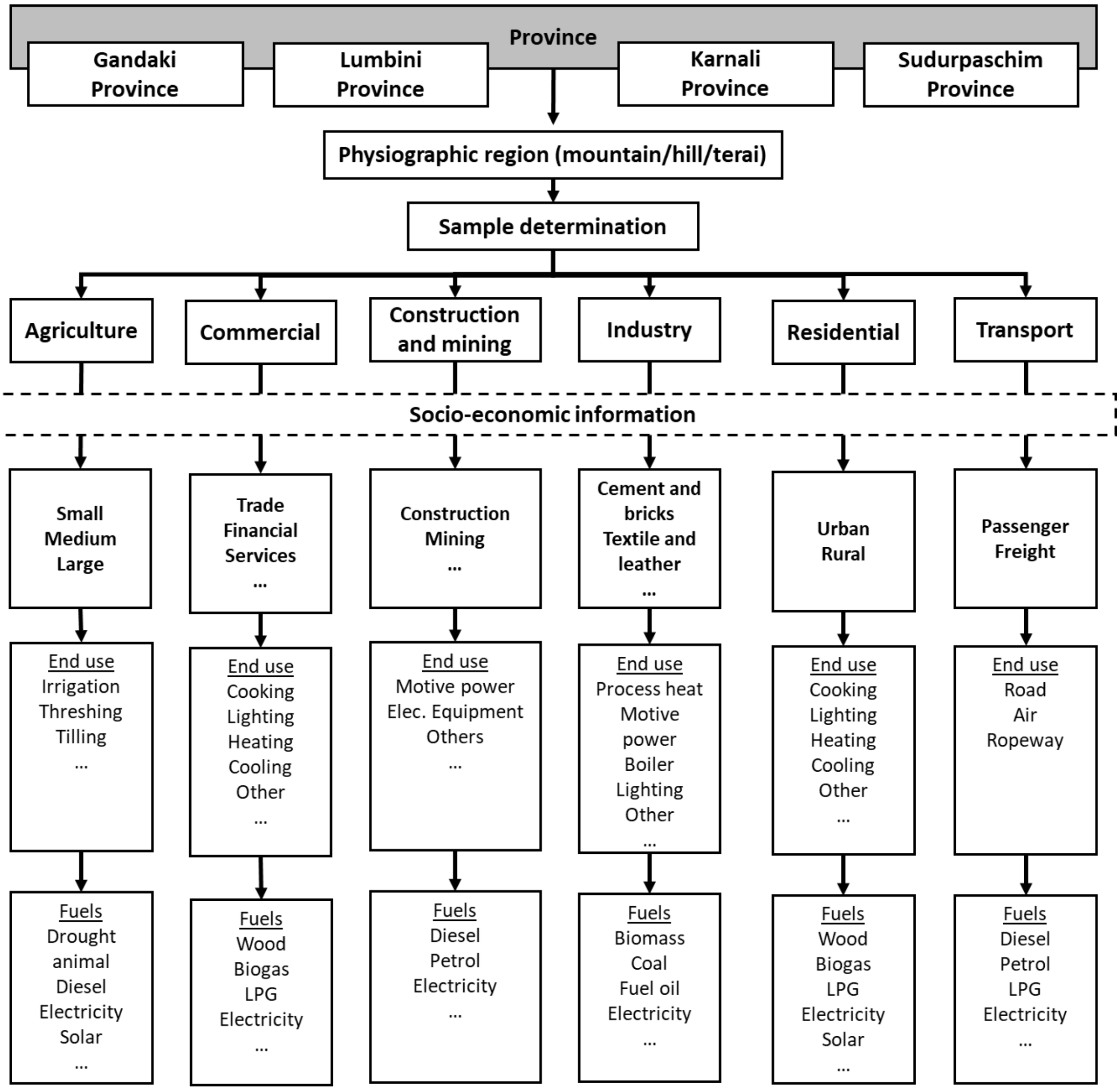
BOX 1: ENERGY SECTOR AND RESOURCES
State of Current Energy Demand and Changes Over Time by Sectors of Energy Uses: *a.* Residential (Household) Sector *b.* Industrial/Production Sector *c.* Commercial/ Service Sector *d.* Agricultural sector *e.* Transport Sector *f.* Construction and Mining Sector Supply 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 the given in Box 2 for Karnali Province.

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 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
Mountain				
Humla	11,484	55,496	-	55,496
Dolpa	9,429	20,472	22,487	42,959
Jumla	24,496	97,420	20,973	118,393
Kalikot	26,956	88,853	56,064	144,917
Mugu	9,883	26,602	25,692	52,294
Hills				
Dailekh	55,708	129,520	123,799	253,319
Jajarkot	38,054	84,110	105,255	189,365
Rukum West	37,702	66,184	99,055	165,239
Salyan	55,400	136,173	102,495	238,668
Surkhet	99,326	92,618	320,714	413,332
Total	368,438	797,448	876,534	1,673,982

(CBS, 2022)

This study adopted a combination of quantitative and qualitative approaches. Data was collected mainly form 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

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

	Total Samples	Response rate
Agriculture	3780	101%
Commercial	3306	101%
Industrial	33	194%
Residential	3810	101%
Transport	303	116%
Construction and Mining	60	140%

Data collection methodology of six sectors were adopted as follows.

- **Residential Sector: SDG**

For this study in the residential sector, each district was considered as the ultimate population area for estimation, and the household of each district was considered as the primary sample unit (PSU). Population size was considered as the total household of the district based on the census in 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. A sample of one urban municipality and one rural municipality were collected during the selection of municipality population density and energy consumption study. 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 consumption was calculated from the 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 consumption of district d of sector s [in TJ]

$E_{f,u}$ = energy consumption 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 consumptions 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

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

Energy consumption for the industrial 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 the district, subsequently giving the total energy of the province. The general formula for the approximation of energy in the industry sector is

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

Equation 3

Where,

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

$E_{f,u}$ = energy consumption 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 consumptions 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, boats, cable car, etc. The transport sector is broadly divided into Road Transport (Passenger and Freight), Air transport, and Ropeway, Navigation and Railways sub sectors. 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 categorization. (**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 and goods carrier services. In this sector buses, cars, jeeps, vans, motorcycles, and cable cars are used for passenger services and trucks, lorries, and pickups is classified as 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 a 95% level of confidence, a 5% margin error, and a 5% non-response rate.

Energy consumption for the transport 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 transport sector is

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

Equation 4

Where,

E_p = energy consumption 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 a sample calculation of the commercial sector has been taken from the National Economic Census 2018 by the 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 the 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 services provided. To make representative all sectors during the survey, the commercial sector is classified 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 shall be identified from the government registration office. These numbers 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 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 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 consumption of district d of sector s [in TJ]
$E_{f,u}$	=	energy consumption 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 consumption in all districts.

- **Agriculture Sector:**

In this sector, a farm is the sample unit for the energy consumption survey. For the population of the agriculture sector, land holding as defined by CBS has been taken. The land holdings are separated into three groups as per the 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

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

Equation 6

Where,

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

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

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 Administrative Staff 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 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.

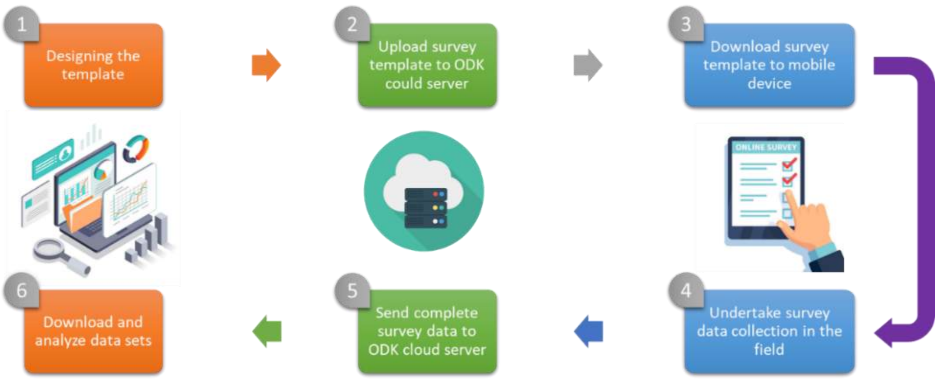


Figure 2-2. Workflow of Survey Design and Data Collection

3 Macroeconomic Status

Nepal has progressed significantly in recent years. Its GDP growth rate has averaged 4.9% in the decade of 2009 to 2019 leading to a 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 Nepal being highly susceptible to climate change. Though Nepal's contribution to GHG emissions to the emission space is significantly negligible 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 a huge impact on the 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 COVID-19 pandemic left an unexpected and adverse effect on the economy at both the national and the provincial levels in FY 2019/20 and in its subsequent years of 2020/21 and 2021/22 but with were seen decreasing over time. The annual GDP growth rate at purchasers' prices in the country was reduced to -2.37% in FY 2019/20. In the same fiscal year, the annual GDP growth rate of Karnali Province did not fall as with Gandaki and Lumbini Provinces, rather it increased to 1.39%. The adverse effects of COVID-19 on Karnali Province were comparatively less in FY 2019/20 and its succeeding fiscal years as its economy is mostly based on primitive sectors and it is relatively less modernized. The annual GDP growth rate of the country in 2020/21 and 2021/22 were both positive and they were 4.25% and 5.84% respectively as the adverse effect of COVID-19 has gradually reduced. In the meantime, those of Karnali Province were also positive and increasing, i.e., 4.34% and 5.47% respectively in those two years, 2020/21 and 2021/22. This decreasing adverse effect of COVID-19 on economic activities at both levels in FY 2021/22 assisted in increasing the economic growth rates of all provinces compared to the pandemic FY 2020/21.

Figure 3-1 depicts that in the fiscal year 2021/22 the estimated GDP at purchasers' prices was Rs. 4,851,625 million, out of which, Karnali Province contributed Rs. 197,998 million (4.08%) to the national GDP. As the effects of COVID-19 decreased, the estimated economic growth rate was at 5.84% in the country whereas; the estimated annual growth rate Karnali Province was at 5.47% in the same fiscal year based on GDP at purchasers' prices.

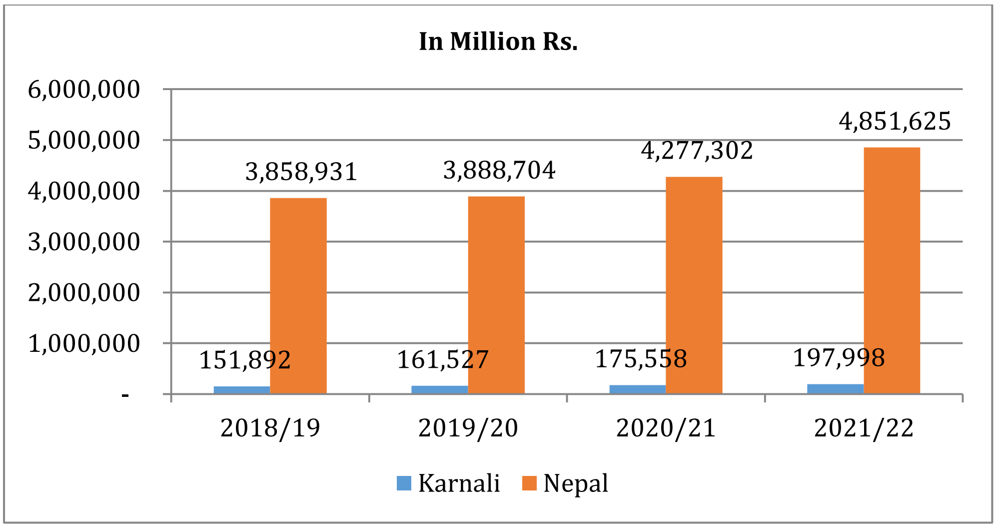


Figure 3-1. GDP at Consumers' Prices of Karnali Province and Nepal (in million NPR)

Except annual growth rate of primary sector GDP (3.9%), those of both secondary GDP (-0.2%) and Tertiary GDP (-1.4%) were negative in Karnali Province in FY 2019/20 while considering GDP at basic prices. In this province, annual growth rate of secondary GDP rapidly increased to 4.1% in 2020/21 and 8.3% in 2021/22 compared to other sectoral GDPs. Primary sector GDP further declined in both succeeding post COVID-19 fiscal years 2020/21 and 2021/22 but remained positive unlike to other sectors. Adverse effects of COVID-19 on this sector do exist till now as growth rates of these broad sectors could not resumed the level of pre COVID-19 fiscal year. Similarly, the same situation exists in tertiary sector, but its growth rate was slightly higher than that of primary sector in succeeding post COVID-19 years **(Figure 3-2).**

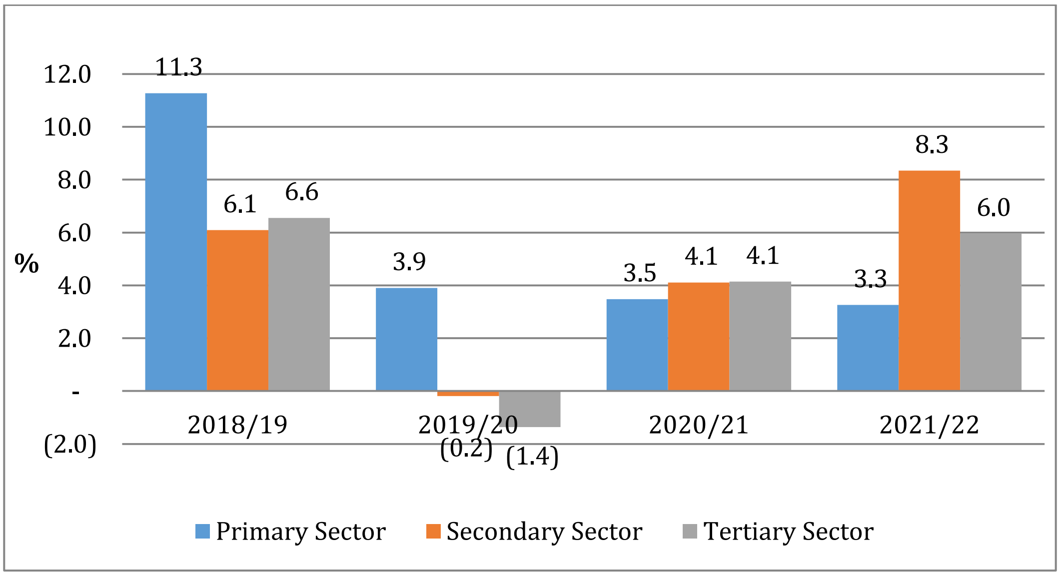


Figure 3-2. Annual Broad Sectoral Growth Rates in Karnali Province During (2018/19-2021/22)

Figure 3-3 shows that the major contributing sector to provincial GDP was the tertiary sector having around 57.4% share, whereas primary and secondary sectors contributed around 31.7% and 10.9% respectively in 2021/22. The composition remained the same in previous FYs. The tertiary sector has gradually replaced the primary and secondary sectors. The share of the secondary sector has been mildly declining despite having a rising trend in its annual GDP growth rate in succeeding post COVID-19 fiscal years.

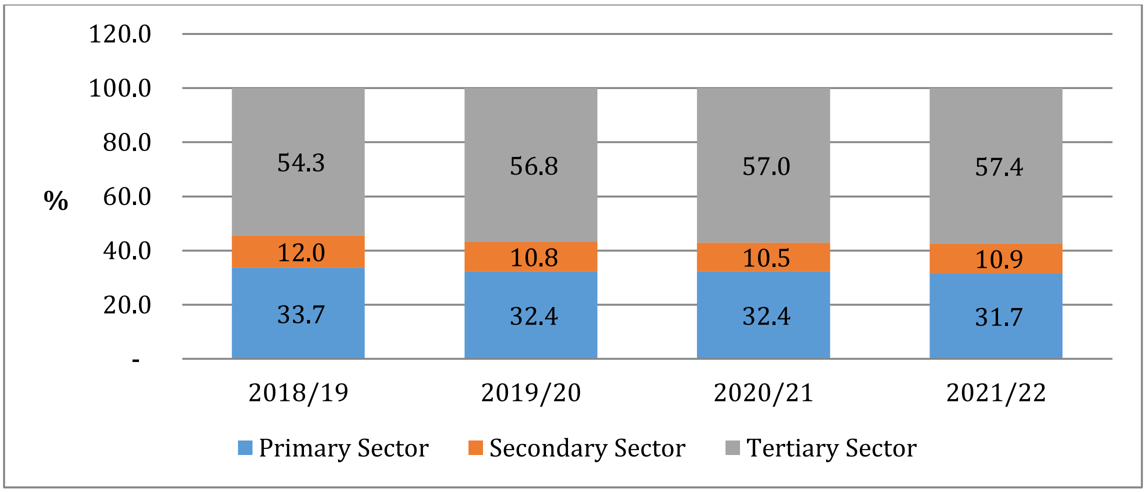


Figure 3-3. Composition of GDP at Basic Prices in Karnali Province

The contribution of Karnali Province to national GDP at basic prices is around 4.1% in FY 2021/22 (**Figure 3-4**). The primary sector contributes around 5.3%, the secondary sector 3.2% and the tertiary sector 3.8% to their respective national sectoral GDP. Contributions of both provincial and all sectors are almost stable, and no remarkable changes are found. In this province, the primary sector has been contributing relatively more than the other sectors. Per capita income in Karnali Province was estimated lower (US$ 964) than the national per capita income (US$ 1,372) in FY 2021/22.

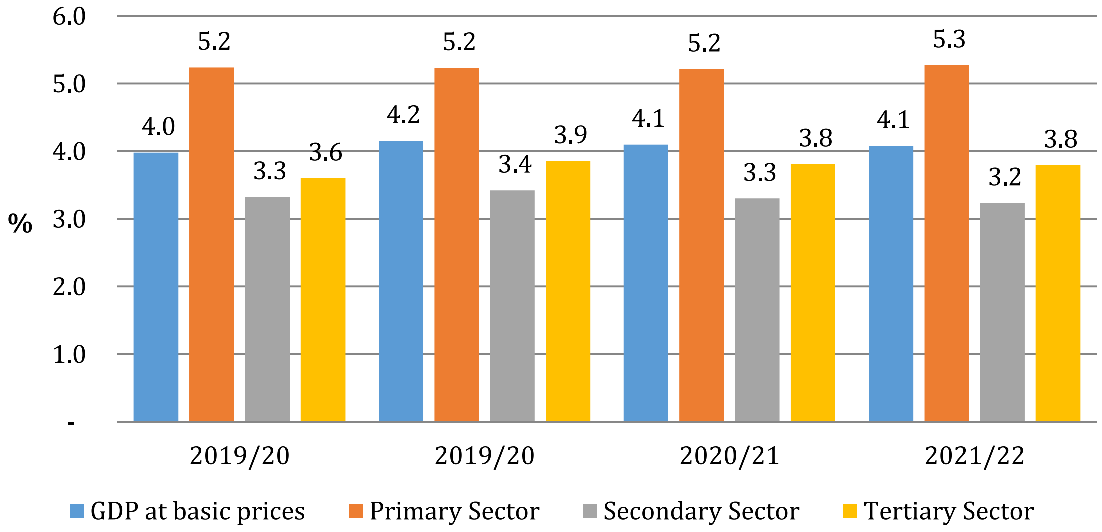


Figure 3-4. Contribution of Karnali Province to National GDP at Current Basic Prices by Sector

3.2 Public Finance

Revenue and expenditure of Karnali Province as a percentage of its provincial GDP were 4.37% and 12.56% respectively in FY 2020/21. Both revenue and expenditure percentages of this province were comparatively higher as the amount of its provincial GDP which was relatively low.

Table 3-1 shows that both national and provincial total expenditures were increased at a faster rate. The total expenditure of Karnali Province was Rs. 10,016 million in FY 2018/19 and increased to Rs. 22,042 million, more than double in two years. The weight or provincial share of national total expenditure was also increasing from 8.9% in FY 2018/19 to 11.7% in 2020/21. The ratio of capital expenditure in Karnali Province was increasing as that at the national level.

Table 3-1. Capital Expenditure Pattern of Provincial Government of Karnali Province

FY	Total expenditure in Rs. million	Weight	Ratio of capital expenses (%)	National total expenditure in Rs. million	Ratio of capital expenses (%)
2018/19	10,016	0.089	54.060	112,090	54.42
2019/20	16,880	0.108	56.490	156,114	57.21
2020/21	22,042	0.117	61.570	188,829	59.34

Source: Financial Comptroller General, 2022

The provincial expenditure of government of Karnali Province was Rs. 22,042 million (i.e., 11.67% of national total expenditure) in FY 2020/21 **(Table 3-2).** The total receipt of the province was Rs. 33,271 million (12.54% of national total receipts) in the same year. 66.3% of the total receipt was utilized as total expenditure but revenue contributed only 23.0% to total receipt. Total expenditure was covered only 34.8% by revenue in this province. Grants contributed 44.0% to total receipt. Thus, the major source of total receipt was grants.

Table 3-2. Expenditure and Revenue of Karnali Province in FY 2020/21

Description	In Rs. Milliion		Share of Karnali (%)	Utilization of funds	
	Karnali	Nepal		Karnali	Nepal
Provincial expenditure	22,042	188,829	11.67	66.3	71.2
Revenue	7,667	87,944	8.72	23.0	33.2
Tax	7,538	77,009	9.79	22.7	29.0
Others	129	10,936	1.18	0.4	4.1
Other receipt including irregularities	10,963	66,410	16.51	32.9	25.0
Grants	14,641	110,348	13.27	44.0	41.6
Repayment of loan and investment	-	541	-	-	0.2
Total receipt	33,271	265,243	12.54	100.0	100.0
Provincial reserved funds (surplus +/loss-)	(11,229)	(76,415)			

Source: Financial Comptroller General, 2022

Table 3-3 shows that the provincial government of Karnali Province spent Rs. 5,927 million, out of which 54.3% was recurrent expenditure and 45.7% was capital expenditure in FY 2021/22.

Table 3-3. Expenditure Pattern of Provincial Government in Karnali Province in 2021/22

	in Rs. Million	
Province	**Karnali**	**Nepal**
Recurrent expenditure	3,218	35,449
Capital expenditure	2,709	28,591
Financing	-	1,000
Total expenditure	5,927	65,041
Expenditure weight	9.1%	100.0%

Source: Financial Comptroller General, 2022

Total number of branches of banks and financial institutions in Karnali Province in 2021/22 (Feb/March 2022) was 451, which was 4.0% of national total branches, 11,349 and persons per branch was 3,758 in the same year. Thus, financial access in Karnali Province was worst compared to that in nation (2,572 persons per branch) **(Table 3-4).**

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

Province	**Karnali**	**Nepal**
Commercial Bank	197	4,930
Development bank	21	1,086
Financial companies	3	257
Micro finance	230	5,076
Total	451	11,349
Share (%)	4.0	100.0
Population** (persons /branch)	3,758	2,572

Source: Nepal Rastra Bank, 2022; **CBS

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 political 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 domestic insurgency problem and political instability in the country. The conflict and political instability were 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 turmoil in the country. A shortage of agricultural labor 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 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 15th 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 the **Table 3-5 and Table 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)" 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, the 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 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

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

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	40.70	(4.00)	2.50	1.70	1.70
ATCA1	(0.90)	0.60	0.40	0.30	0.40
CDIAG1	3.00	2.80	2.10	1.80	2.10
CDIIND1	12.20	9.40	9.50	9.40	9.50
CDISERV1	7.20	6.70	6.90	7.00	6.90

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.

<u>Other Exogenous Variables:</u>

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 **Table 3-8**.

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	4.70	1.90	1.80	1.50	1.70
FXGS1	2.10	4.10	1.40	1.20	1.60
GFGRANT1	(12.00)	6.70	1.90	1.00	2.70
GFI_N1	14.30	1.20	2.30	2.00	2.20
INDCPI1	6.20	5.60	4.60	4.20	4.70
POP1	1.00	1.10	1.10	1.00	1.10

- **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 10,000 MW 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 must be increased for higher growths to achieve the abovementioned goals. Sustainable development goals have also to be achieved. That’s why, the investments for these broad economic sectors are projected exogenously. ATCA1 and ACMFERT1 are expected to be increased. 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	40.70	(1.00)	3.80	4.60	4.30
ATCA1_1	(0.90)	0.70	0.70	0.80	0.70
CDIAG1_1	3.00	3.80	4.90	5.80	4.90
CDIIND1_1	12.20	9.60	10.80	11.80	10.80
CDISERV1_1	7.20	6.70	7.50	8.50	7.70

- **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 been 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 **Table 3-10.**

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	40.70	(1.00)	4.30	5.30	4.60
ATCA1_2	(0.90)	0.70	0.70	0.80	0.70
CDIAG1_2	3.00	4.10	5.40	6.90	5.60
CDIIND1_2	12.20	10.20	11.60	13.00	11.80
CDISERV1_2	7.20	7.50	8.80	9.80	8.80

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 one particular image of how the future could unfold under certain circumstance. Scenarios provide a framework for exploring future perspectives, including various combinations of activities, technology options and their implications. Scenarios are useful tools for investigating alternative future developments and their implications, for learning about the behavior of complex systems such as energy and environment systems and for policy-making decisions related to them(Nakicenovic, 2000).

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 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 were taken from the targets set for national economy in government documents or was 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

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

*Details are given 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. Meanwhile the transport sector, which is responsible for transport of person as well as goods, it is affected both by population as well as economic outputs – i.e. GDP. For the rest of the economically active sectors, their respective economic outputs are the driving factors in energy demand.

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 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[8], 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, in MAED for energy demand projection as it is one of the robust, freely available energy demand analysis software. Secondly, TIMES model is used as the MAED is limited or demand projection only, while the TIMES model 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.

[8] 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.

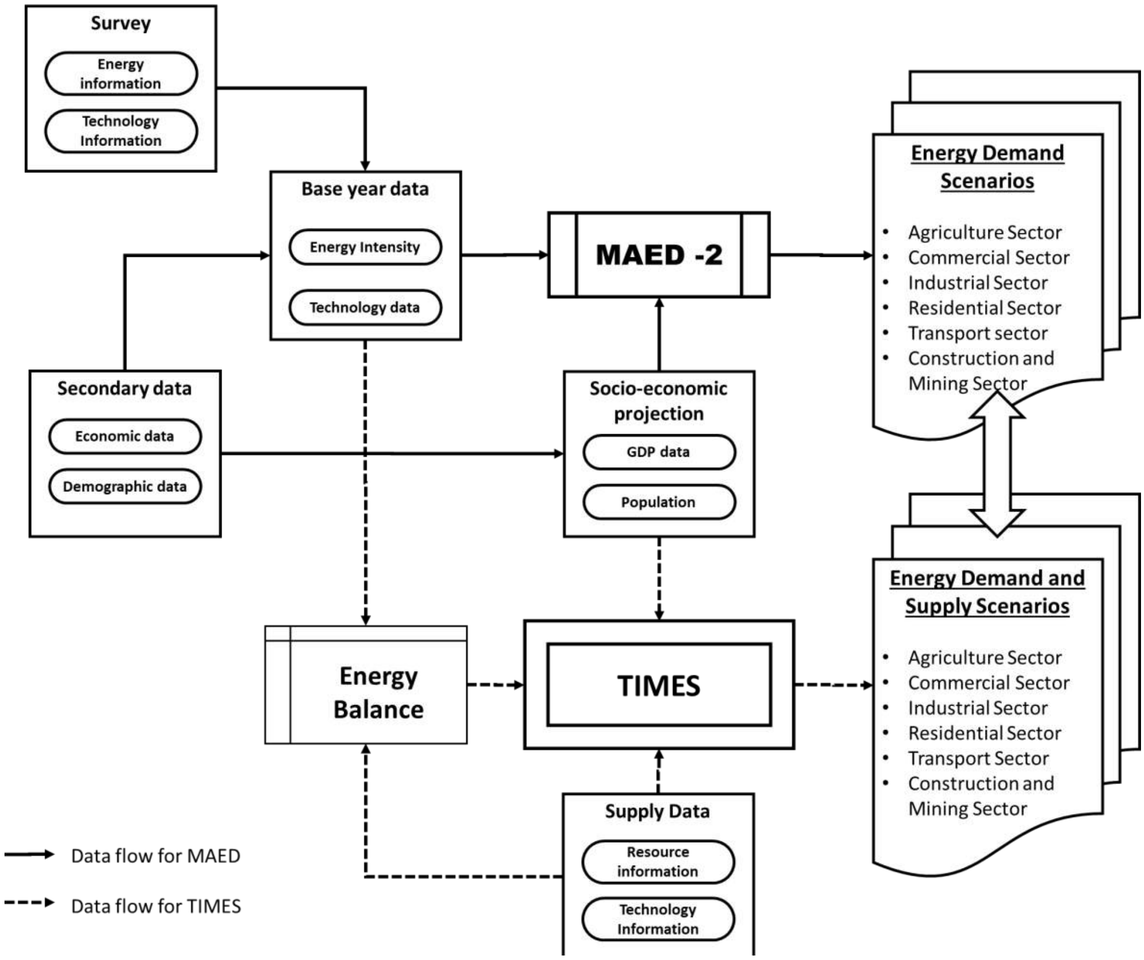


Figure 4-1. Methodological Framework of Projection in MAED and TIMES

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 out in the MAED framework. The results and scenarios developed using such a 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.

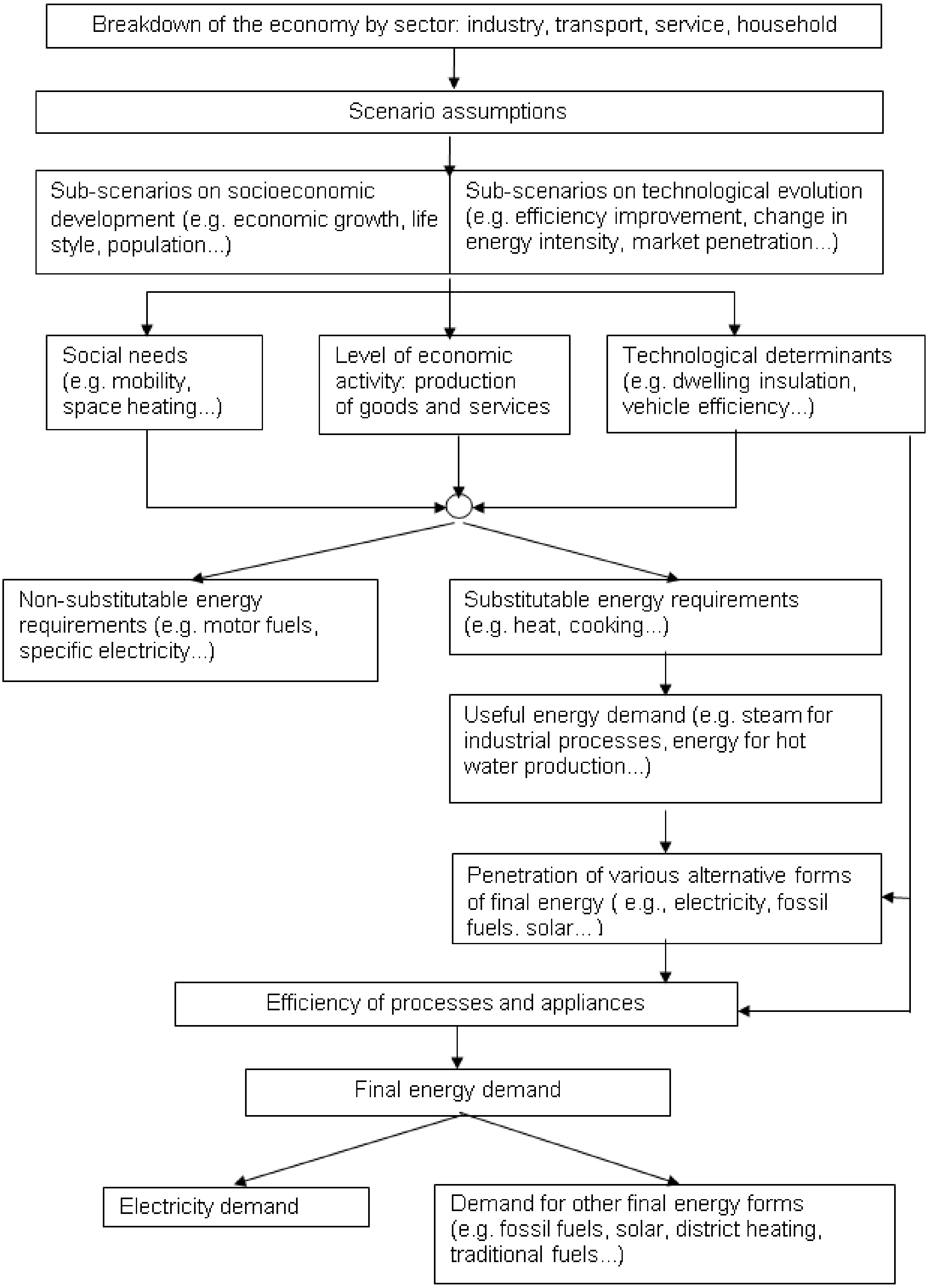


Figure 4-2. Scheme Used to Project Useful and Final Energy Demand in Module 1 of MAED

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)**

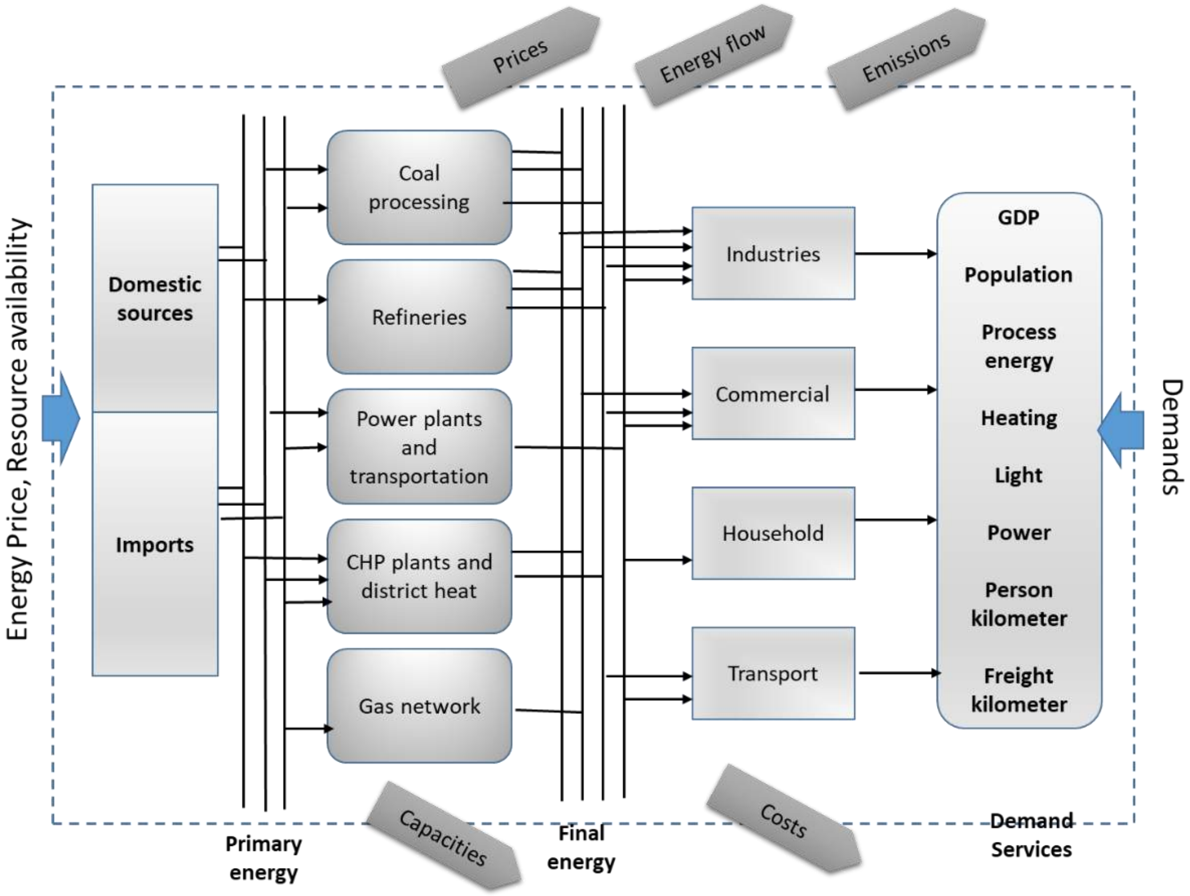


Figure 4-3. Structure of TIMES Framework

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

TIMES Model Run and Solutions

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

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

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

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

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

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

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

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

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

Equation 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 plus variables for technology sets alone, both for the end-use and conversion technologies. Apart from this, the resources sets and other parameters such as emissions and costs multiply the extent of variables accordingly.

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

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.**

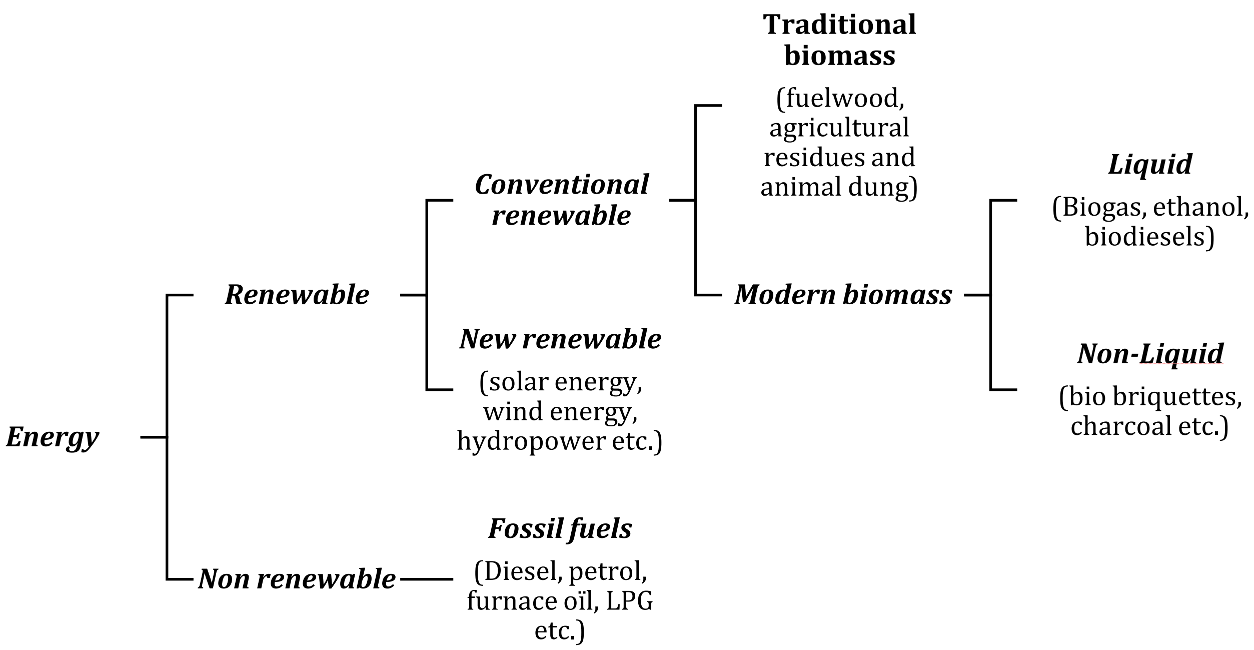


Figure 5-1. Energy Classification for Nepal[9]

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

5.1 Solid Biomass

Karnali Province of Nepal is blessed by nature with lush forests in 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 Karnali and its provincial territories, and abundant alluvial soil. Although deforested to some level, there is still good forest cover throughout the

[9] As per Terms of Reference

province. But urbanization and agriculture have encroached on good forest lands which are prominent, especially in the Surkhet district. Similarly, human pressure for fuelwood in the past has led to deforestation. Despite this, Karnali Province has good potential for forest management and production with its rich soil and history of community forestry. But rampant poverty in districts like Kalikot makes the people overly reliant on cheap bioenergy.

5.1.1 Forests in Karnali Province

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

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

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

Subalpine forests occur between 3,000 – 4,100 meters and are mainly comprised of small and generally ill-formed trees of *Abies spectabilis*, *Picea smithiana*, *Betula utilis*, and *Rhododendron* spp. Alpine scrub vegetation occurs between the treeline (around 4,000 meters) and snowline (around 5,500 meters). **Table 5-1** shows forest areas and major species of Karnali.

Table 5-1. Summary of Physio Graphic Zone of the Karnali Province

SN	physiographic zone	altitude (m)	districts	forest area (ha)	major species	Total Stem volume (m^3)	Growth rate %
1	Middle mountain	500-3,000	Surkhet, Dailekh, Jajarkot, Salya, Rukum	575,954	chima-castanopsis, pinus, oak, alnus	71,568,044	medium
2	Higher mountain	3,000-5,000	Jumla, Humla, Mugu, Dolpa, Kalikot	601,079	rhododendron, abies, acer, betula, picea	13,5387,034	slow

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

5.1.2 Forest Management in Karnali Province

Shey-Phoksundo and Rara National Park are protected areas in the province, which are managed for biodiversity conservation. All remaining forests are managed for production which include timber, fuelwood, and non-timber forest products. Most prominent forest management in Karnali Province is community forests, although there are limited Collaborative Forest Management and block forest managed by government.

Area of forests in Karnali Province under community forest management is given below**. Table 5-2** shows that 3,13,648 ha area is handed over to 2650 forest user groups (DoF, 2019). This figure is low as compared to community forests area handed over in other hill districts.

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

SN	Districts	No of UG	Area Managed
1	Surkhet	431	80,621
2	Dailekh	367	31,282
3	Jajarkot	228	21,317
4	Salyan	558	54,689
5	Rukum	470	27,801
6	Kalikot	190	14,108
7	Jumla	197	26,369
8	Humla	67	23,512
9	Mugu	91	11,037
10	Dolpa	51	22,912
	Total	**2,650**	**3,13,648**

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 (Lauri et al. 2014). 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. It accounted for 70% and biomass for 92% of Nepal's total energy consumption. The main use of Nepal’s forests is to provide biomass to satisfy the energy needs of rural and remote regions. Fuelwood is used for several purposes like cooking, heating, lighting, etc. Historically, Nepal’s rural populations have been meeting their energy needs from traditional sources like fuelwood and other bio-mass resources (AEPC, 2000). Most of the fuelwood has been reported to be derived from forests with some trees outside the forest and trees growing in 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 accounts 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 and had in resulted tremendous pressure on existing forests. Local communities bring hundreds of cycle loads of fuelwood to their villages from forests in rural areas. But, due to the migration of the population into town, the rural population has decreased in recent years.

5.1.4 Effect of Fuelwood Collection to Forest

In past decades, because of the increasing population, the area under agriculture expanded, and forests shrank. The forest area 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 the Kailali district alone, the encroached forest land is 22,115 ha. 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). On the other hand, due to poverty, the demand for fuelwood increased despite the rapid growth in the commercial energy sector. Fuelwood is practically free if people afford time for collection and foraging. Large quantity of fuelwood is being collected from community and government-managed forest by the locals.

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 forest use is diverse and an integral part of the subsistence economy. The government of Nepal is the predominant supplier of fuelwood products in Nepal. The supply of fuelwood in 2011 was estimated at 2.58 million tons, 5.44 million tons, and 0.94 million tons for Terai, hills, and the mountain regions respectively. The supply would increase to 3.72 million tons, 6.96 million tons and 1.13 million tons in 2020 and 5.07 million tons, 9.60 million tons and 1.51 million tons in 2030 for Terai, hills, and mountains respectively. Mathematically fuelwood demand is a function of households, their fuelwood use and per capita consumption.:

Fuel Demand=f (No. of HH, the percentage using fuelwood, per capita consumption) (MFSC 2013).

- **Fuelwood from Community Based Forests**

Most of the forest products in Karnali Province come either from community forests or government forests or private forests. There, the government forests are mostly matured and degraded (Paudel et al 2021). Therefore, these forests have small growing stock. In the past, forest management plans that were formulated failed to manage the forests on a sustainable basis. Felling of trees in government forests is often limited to the clearing of the site for different projects like roads, resettlement of villagers, transmission lines, irrigation channels, industrial states, etc. Lately, pilot forest management programs have been initiated in community and collaborative forests. The results of these forest management programs have been highly positive. Therefore, in the future managed forest areas will be increased and this will produce more forest products like timber and fuelwood.

5.1.6 Potential Increments

Sustainable management of forests in Nepal could not only increase and stabilize the supply of forest products, but also help in contributing to the livelihood of the people involved in 17, 685 community forests, and 2.18 million households are involved in community forest management (DoF, 2012) and collaborative forest management. 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 5-3** provides the fuelwood collection in the Karnali Province.

Table 5-3. Forest Area and Potential Fuelwood Production in Current

	Forest Area	Accessible forest area	Fuelwood Production/year in m^3	Fuelwood Production/year in kilo ton
Surkhet	1,72,220	1,54,988	3,48,262	247.61
Dailekh	77,475	69,727	1,56,669	111.39
Jajarkot	1,33,268	1,19,941	2,69,493	191.60
Salyan	1,28,274	1,15,446	2,59,395	184.42
Rukum W	64,717	58,245	1,30,870	93.04
Kalikot	1,14,308	1,02,877	4,19,430	298.21
Jumla	1,20,412	1,08,370	4,41,828	314.13
Humla	1,26,748	1,14,073	4,65,076	330.66
Mugu	1,18,628	1,06,765	4,35,282	309.48
Dolpa	1,20,983	1,08,884	4,43,923	315.62
Total			**33,70,229**	**2,396.23**

Note: GS per hectare in terai is 167 m^3, hills 124 $m^{3,}$ and high hills 225 m^3. 40% of it is fuelwood.

Thus, annual fuelwood from the whole Karnali Province is 3,370,229 m^3 (This is a harvestable quantity). This volume accounts for 11 categories, 10 defined species, and 1 other (miscellaneous). And to classify timber production as per species, the proportion of stem volume of each species is multiplied to 3,370,229 m^3. Thus, the obtained value is converted to the kilogram and or tone using wood density (average 1 m^3 =711 kg) and totaled to final fuelwood 2,396.23 kilo tons.

5.2 Biogas in Karnali Province

- **Livestock in the Karnali Province**

The potential of biogas production is directly related to the availability of local feedstock in the area. In Nepal, animal dung is considered the major feedstock for biogas production at the household level. The generation of biogas reduces the dependency on fossil fuels which are non-renewable and mitigates attendant global warming continuously being caused by the combustion of fossil fuels. It also helps to reduce greenhouse gas emissions from methane (AgStar, 2011). Biogas being a clean fuel also helps in the control of air pollution resulting from the burning of fossil fuels. The residue produced from the digester acts as a good fertilizer that can be applied to the field.

The number of livestock and collectible dung plays a major role in determining the biogas. production potential. The number of livestock in different districts of Karnali Province is given in **Table 5-4.**

Table 5-4. Numbers of Livestock in Karnali Province (Fiscal Year 2077/78)

District	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Dailekh	81,710	57,778	15,609	236,017	12,052	161,650	1,250
Dolpa	22,456	3,327	36,095	52,865	108	42,329	87
Humla	16,646	2,851	30,801	73,395	118	15,406	353
Jajarkot	38,950	33,362	25,542	118,844	2,757	152,066	724
Jumla	66,040	3,601	73,241	44,677	325	67,362	568
Kalikot	25,150	29,136	36,031	84,618	1,635	63,095	156
Mugu	38,400	14,095	42,311	47,689	78	12,540	143
Salyan	117,043	71,134	14,651	315,438	12,484	428,225	2,676
Surkhet	53,389	41,839	5,892	334,720	12,474	353,249	3,104
Western Rukum	26,612	52,404	26,929	165,118	3,332	403,581	645
Total	**486,396**	**309,527**	**307,102**	**1,473,381**	**45,363**	**1,699,503**	**9,706**

(Source: MoALD, 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 Karnali Province can be estimated as shown in **Table 5-5.**

Table 5-5. Dung Production in Karnali Province

District	Cattle	Buffaloe s	Dung produced from cattle tons/ year	Dung produced from buffalo tons/ year	Total dung production tons/Year
Dailekh	81,710	57,778	298,242	316,335	614,576
Dolpa	22,456	3,327	81,964	18,215	100,180
Humla	16,646	2,851	60,758	15,609	76,367
Jajarkot	38,950	33,362	142,168	182,657	324,824
Jumla	66,040	3,601	241,046	19,715	260,761
Kalikot	25,150	29,136	91,798	159,520	251,317
Mugu	38,400	14,095	140,160	77,170	217,330
Salyan	117,043	71,134	427,207	389,459	816,666
Surkhet	53,389	41,839	194,870	229,069	423,938
Western Rukum	26,612	52,404	97,134	286,912	384,046
Total	**486,396**	**309,527**	**1,775,345**	**1,694,660**	**3,470,006**

5.2.1 Potential of Biogas Energy Production Per Year

The estimation of potential biogas production in Karnali Province is done considering the biogas production factor as 0.036 cubic meters per kg of dung (WECS, 2010), and its district-wise production potential in cubic meters for the year 2020/2021 is estimated as below. Per cubic meter of biogas is further converted into energy using a conversion factor of 1 cubic meter of dung equals 20 MJ (Vaid, V. & Garg, S., 2013), **Table 5-6** shows the potential energy production from biogas.

Table 5-6. Potential of Biogas Production in 2020/2021

District	Total dung production “000” tons/Year	Biogas in “000” cubic meter	Energy in “000” Gj per year	Potential percentage	Potential in 000 GJ
Dailekh	615	22.125	442.49	0.75	331.87
Dolpa	100	3.606	72.13	0.5	36.06
Humla	76	2.749	54.98	0.5	27.49
Jajarkot	325	11.694	233.87	0.75	175.41
Jumla	261	9.387	187.75	0.5	93.87
Kalikot	251	9.047	180.95	0.5	90.47
Mugu	217	7.824	156.48	0.5	78.24
Salyan	817	29.400	588.00	0.75	441.00
Surkhet	424	15.262	305.24	0.75	228.93
Western Rukum	384	13.826	276.51	0.75	207.38
Total	**3,470**	**124.920**	**2,498.40**		**1,710.73**

Temperature plays a significant role in the production and efficiency of biogas plants. At lower temperatures, biogas production is low. The Terai is a lowland and is characterized by high temperatures and a humid climate. The Hill area is of moderate altitude and mild climate. The Mountain region is too cold for biogas technology. Here, the potential of biogas production is considered 50% for 5 high hill districts, and 75% for 5 mid hill districts. As per **Table 5-6**, the production of biogas for Karnali Province is 1,710 thousand GJ per year.

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

Waste-to-energy (W2E) generation is one of the promising sustainable alternatives for biogas and electricity generation from discarded organic waste materials and by-products from various commercial/ industrial activities and municipal waste. It is also a solid alternative to solid waste management since these intend to recover energy from the waste thereby reducing the quantity of waste sent to landfill sites. It is environmentally beneficial by nature as it also helps in reducing the amount of greenhouse gases emission from landfill sites as well as minimizing carbon emissions from incineration/ burning of waste.

Some of the promising sectors for W2E conversion are (i) the commercial sector (livestock farms - cattle farms, pig farms, and poultry farms), (ii) industrial sector (having high organic wastes like sugar mills, distilleries, and breweries, food processing industries, hotels, large restaurants, private schools/collages, registered markets, etc.) and (iii) municipal sector, where the quantity of waste is economically available for operating large-scale biogas production such that it can be used for bottling, pipeline, electricity generation, or other end use.

Alternative Energy Promotion Centre (AEPC) with support from The World Bank under the Scaling up Renewable Energy Program (SREP) is working to develop a market for large-scale Commercial Biogas and Municipal Solid Waste (MSW) for energy projects in Nepal. AEPC is supporting this new sector by conducting feasibility studies at potential municipalities and commercial business entities and also providing various subsidy schemes based on the size of the plant and energy generation in the form of biomass energy or end-use electricity.

AEPC has also conducted some studies related to W2E potential for selected municipalities and districts during various timeframes, however detailed national-level study is still lacking in this sector.

The estimated potential of waste to energy potential from commercial/ industrial and municipal solid waste for various districts of Karnali Province based on the secondary data from the study reports from AEPC is presented in the **Table 5-7.**

Table 5-7. Potential of Waste to Energy Production per year in Karnali Province

District	District population (2078)	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
Dailekh*	253,319	6.54	366.72	2.39	133.85	2,677.07
Dolpa*	42,959	1.11	62.19	0.40	22.70	453.99
Humla*	55,496	1.43	80.34	0.52	29.32	586.48
Jajarkot*	189,365	4.89	274.14	1.79	100.06	2,001.20
Jumla*	119,377	3.08	172.82	1.13	63.08	1,261.57
Kalikot*	144,917	3.74	209.79	1.37	76.57	1,531.48
Mugu*	66,658	1.72	96.50	0.63	35.22	704.44
Salyan*	238,668	6.16	345.51	2.25	126.11	2,522.23
Surkhet **	417,776	10.79	604.80	3.94	220.75	4,415.04
Western Rukum*	166,354	4.30	240.82	1.57	87.90	1,758.02
Total	**1,694,889**	**43.77**	**2,453.63**	**15.98**	**895.58**	**17,911.52**

(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 total organic waste considered here is organic municipal waste which is the segregated part of the total municipal waste excluding non-organic dumping waste. The commercially feasible waste generated from commercial and industrial activities is comparatively very small in quantity and thus considered not feasible for energy generation projects.

The W2E potential for all the districts except Surkhet district has been calculated based on the proportionating population density with reference to Surkhet districts since no field studies have been conducted in these districts.

Since technically feasible and financially viable W2E projects demand an uninterruptable and sizable quantity of waste economically available for the 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), 52.1% of the population of each district have been considered to live in the respective city area.

From the table given above, it is seen that Dolpa, Humla, and Mugu districts had the least W2E potential and Surkhet has comparatively high potential within the province. The total W2E potential energy is found to be 7,911 thousand GJ per year which is quite low compared to other provinces.

5.3 Energy from Agriculture Residues

Agriculture waste is also the main source of fuel because it is already available in homes during the harvest of agriculture crops. The area used for farming different crops is shown in **Table 5-8.**

Table 5-8. Area of Different Crop in Districts in 2021

	Area in Ha						
Districts	**Paddy**	**Maize**	**Wheat**	**Buckwheat**	**Oil seed**	**Millet**	**Barley**
Dolpa	198	2359	3000	807	3	280	334
Mugu	894	560	1780	609	73	4264	1034
Humla	567	149	1072	806	109	1308	642
Jumla	2821	4413	2300	87	128	3737	3003
Kalikot	2429	3036	5606	123	282	1241	821
Rukum W	1737	9913	9690	35	467	466	413
Salyan	7059	19047	14217	66	3653	1031	749
Jajarkot	2956	10206	10432	31	1090	1833	615
Dailekh	7907	21057	13710	28	1151	2566	181
Surkhet	12463	14943	12191	56	10871	2235	631
Total	**39041**	**85684**	**73998**	**2648**	**17826**	**18962**	**8423**

After collecting cultivated areas of different crops, we can come to estimate residues produced as in **Table 5-9.**

Table 5-9. Energy from Agriculture Waste /Year

Districts	Residue of crops in tons							Total residue in tons	Energy produced in GJ
	Paddy	Maize	Wheat	Buckwheat	Oil seed	Millet	Barley		
Dolpa	1,168	12,856	10,110	1,210	4	532	634	26,515	397,735
Mugu	5,274	3,052	5,998	913	93	8,101	1,964	25,398	380,975
Humla	3,345	812	3,612	1,209	140	2,485	1,219	12,823	192,352
Jumla	16,643	24,050	7,751	130	164	7,100	5,705	61,546	923,191
Kalikot	14,331	16,546	18,892	184	361	2,357	1,560	54,232	813,491
RukumW	10,248	54,025	32,655	52	598	885	784	99,249	1,488,747
Salyan	41,648	103,806	47,911	99	4,676	1,959	1,423	201,522	3,022,835
Jajarkot	17,440	55,622	35,155	46	1,395	3,482	1,168	114,311	1,714,677
Dailekh	46,651	114,760	46,202	42	1,473	4,875	344	214,349	3,215,238
Surkhet	73,531	81,439	41,083	84	13,915	4,246	1,199	215,499	3,232,485
Total	**230,283**	**466,972**	**249,373**	**3,972**	**22,819**	**36,026**	**16,003**	**1,025,448**	**15,381,730**

Table 5-9 provides an estimate of total agriculture residue produced from different crops and energy produced from these agricultural residues. Total potential energy produced from such waste is **15.38 million** GJ. 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 the import and sales of petroleum products – that includes diesel, petrol, kerosene, LPG, and others is Nepal Oil Corporation (NOC). 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 the NOC. District-wise sales data for 2077-78 are shown in **Table 5-10**. All the units for MS, Diesel, and SKO are in kilo liters except for LPG in metric tons (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 consumption may not tally properly. The sales data from the NOC depot shows that less than 1% of total national sales of diesel, gasoline, and kerosene are consumed in Karnali Province due to limited economic activities in the western part of Nepal, besides individual imports from other provinces.

Table 5-10. Petroleum Sales in 2077-78 in Karnali Province

Districts	MS	HSD	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Dailekh	303	2,798	-	-	-
Jumla	91	864	-	-	-
Kalikot	-	550	-	-	-
Salyan	1,159	5,089	-	-	-
Surkhet	7,432	24,273	445	1,491	-
Western Rukum	397	1,781	-	-	-
Total	**9,382**	**35,355**	**445**	**1,491**	**-**

(NOC 2022)

LPG sales could not be 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 has the 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 shown in **Table 5-11.** Koshi Province, which includes most of the Koshi basin incorporates the highest hydropower potential (22,619 MW)- which is 31.2% of the total hydropower potential. Madhesh province incorporates the lowest hydropower potential (275 MW)-which is 0.4% of the total potential. Similarly, Bagmati, Gandaki, Lumbini, Karnali, and Sudurpashchim Province incorporate 14.6%, 20.7%, 3.7%, 18.9%, and 10.6% of the total potential respectively.

Table 5-11. Distribution of Gross Hydropower Potential Among Different Provinces Based on 3 Major River Basin

SN	Province	Power Potential (MW)	% of Basin Potential (MW)
1	Koshi Province	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. As per NEA 2021, the total installed capacity developed by NEA stands at 582 MW. In addition to NEA's generation, the Independent Power Purchasers (IPPs) significantly contribute to the national hydropower plants' development. The total installed capacity from IPPs stands at 814.6MW. In addition, there is a 53.4 MW addition from thermal power plants and 1.35MW from grid-connected solar power plants. The total installed capacity thus reached 1451 MW by Mid-March 2021. Recently the Upper Tamakoshi Hydropower plant has started its operation adding another 456 MW capacity to the national grid in October 2021.

There is no installed capacity for a hydropower plant developed by NEA in Karnali Province. However, The IPPs have some existing plants and have some plants under construction and planned projects in Karnali Province as shown in **Table 5-12.**

Table 5-12. IPPs Developed, Under Construction and Planned Hydropower Plants

	In operation	Under construction	Planned Projects
	Installed capacity MW	**Installed capacity MW**	**Capacity MW**
Karnali	9.8	2,227	4,295.69

(DoED, 2023)

5.5.2 Electricity Supply

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 2189.91 MW in Integrated Nepal Power System (INPS). The annual energy generation from NEA power plants under Generation Directorate is 3,242.48 GWh, which is about 29.29% of the total energy generation in Nepal (NEA Hydropower Stations, Subsidiary Companies and IPPs) (NEA 2022).

The district-wise electricity supply status as obtained from Nepal Electricity Authority for Karnali Province is shown in **Table 5-13** along with its use in economic sectors. It shows Surkhet district has a comparatively high consumption of electricity due mainly to the number of industries located in the district. Most of the electricity is consumed in the residential sector (66%), followed by the commercial and industrial sectors with 26% and 8% respectively. The agriculture sector consumed 1% of grid electricity and there is no electricity consumption in the transport sector.

Table 5-13. Electricity Sales in 2077-78 in Karnali Province

	Agriculture	Commercial	Industry	Residential	Transport	In TJ
Rukum	-	3.45	0.58	8.04	-	12.07
Salyan	0.02	8.12	1.82	11.62	-	21.59
Dolpa	-	0.40	0.02	0.73	-	1.16
Mugu	0.00	0.56	0.04	1.56	-	2.17
Humla	-	0.80	0.06	2.10	-	2.97
Kalikot	-	0.68	0.12	1.61	-	2.41
Jumla	0.00	1.07	0.03	1.71	-	2.82
Jajarkot	0.01	1.08	0.15	3.25	-	4.48
Dailekh	0.06	2.89	1.06	7.57	-	11.57
Surkhet	1.76	36.84	13.61	105.08	-	157.30
Total	**1.85**	**55.90**	**17.50**	**143.27**	**-**	**218.53**

(NEA, 2022)

5.6 Modern Renewable Energy Sources- Solar & Other 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, it has been able to implement 1851 nos. of mini and micro hydro projects generating 34.47 MW of electricity among which, 186 nos. of projects are implemented in Karnali Province generating 4.96 MW of electricity benefitting 12,907 nos. of rural households. Western Rukum has comparatively more beneficiary households covering 26.29% of the provincial total beneficiaries while Salyan had the least number with only 0.52% coverage. According to AEPC, 2253 nos. of improved water mills, 211,011 nos. of solar home system units, 697 nos. of institutional solar PV System generating 1053.9 kWp, 14 solar irrigation systems, and 33 solar water pumping systems has been installed which covers 19.7%, 26.5%, 19.6%, 0.6% and 17.6% of the total country installation respectively.

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, only 6% of the installation has been done in Karnali Province, i.e., 5,754 Nos. of domestic biogas plants, 80,254 mud ICS and 10,865 metallic ICS **(Table 5-14).**

Table 5-14. Modern Renewable Energy Technologies Installed in Karnali Province

Technologies	Micro Hydro Projects			Improved Water Mill	Solar Home System	Institutional Solar Photovoltaic System	
District	No. Projects	kW	HHs	Numbers	Numbers	Numbers	Wp
Dailekh	16	277.5	2,984	275	42,445	73	1,09,000
Dolpa	9	396	3,593	50	4,797	65	78,645
Humla	17	518.4	4,393	13	4,107	67	91,825
Jajarkot	36	836.7	8,765	295	28,096	72	1,21,500
Jumla	29	830.2	8,053	209	13,292	119	1,70,615
Kalikot	13	581	4,849	591	22,470	66	1,18,500
Mugu	9	217	2,271	11	8,281	48	72,660
Salyan	2	13	257	216	38,256	96	1,39,250
Surkhet	3	79	1,025	493	29,122	62	1,21,000
Western Rukum	52	1,215.5	12,907	100	20,145	29	31,000
Grand Total	**186**	**4,964.3**	**49,097**	**2,253**	**211,011**	**697**	**1,053,995**

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
Dailekh	-	9	233	-	19,910	812
Dolpa	2	-	4	-	-	46
Humla	-	-	2	-	31	2,669
Jajarkot	-	-	95	-	13,317	1,511
Jumla	-	-	6	-	2	818
Kalikot	2	1	264	-	425	1,680
Mugu	5	-	8	-	18	2,372
Salyan	-	3	303	-	22,690	238
Surkhet	5	16	4,805	2	18,977	552
Western Rukum	-	4	34	-	4,884	165
Grand Total	**14**	**33**	**5,754**	**2**	**80,254**	**10,863**

(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 production from own garden as well bought from the nearest market. The household energy production obtained from the survey shows that in Karnali Province there is sufficient supply of agri-residue and animal waste to meet its demand for household purposes. However, in the case of fuelwood, approximately 70% 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. The 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 5-15)**. Details of household energy production of each district are given in Annex.

Table 5-15. Household Energy Production

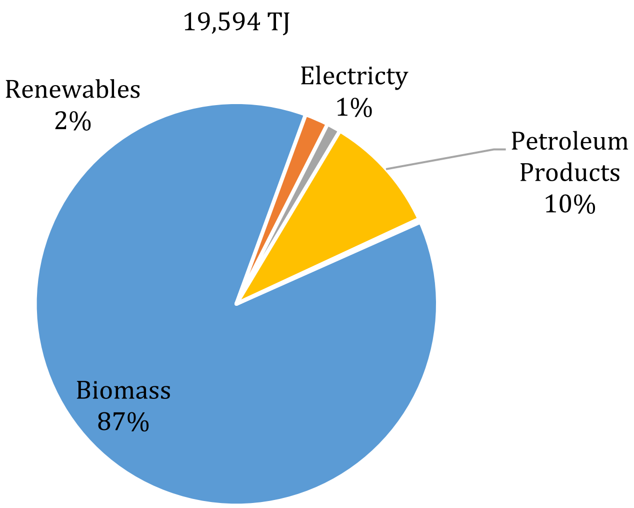
Fuel sources	**TJ**
Fuelwood	11,813.61
Agri residue	25.32
Biogas	11.14
Solar PV	35.29

(Calculated from survey data, 2022)

6 Energy Consumption in 2021/2022

The total final energy consumption (FEC) in Karnali Province was found to be 19,594 TJ. Among the six sectors, the residential sector is the highest energy-consuming sector. Since there are limited economic activities in the province with only a 4% contribution to GDP, energy consumption is considerably low in this province. The abundance of indigenous resources mainly fuelwood in the remote areas could be seen as the share of biomass is comparatively high with 87% of total consumption in the province. As per the NPHS 2021, access to electricity in Karnali Province is 50% through grid and 48% off-grid (especially solar PV systems). In this province, 82% of households still cook on solid biomass, 17% of households' cook on LPG and just 0.1% of households' cook on electricity (NSO, 2023). These figures indicate energy poverty is the highest in Karnali Province compared to other provinces. It clearly shows a strong need for promotion of energy-efficient technologies and an accelerated transition to modern energy resources in the province.

In Karnali Province, the use of fuelwood is still the major resource among biomass used mainly for cooking and water heating purposes in the residential sector **(Figure 6-1).** 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 growing consumption of LPG, decreasing livestock farming as well as people's 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 to institutional use. The consumption of petroleum products is also increasing as some industries still use diesel for electricity generation, mostly where the electricity supply is unreliable.



(Survey, 2022)

Figure 6-1. Energy Consumption Share in Karnali Province by Energy Types

Figure 6-2 also indicates the consumption pattern in different economic sectors. The residential sector is the highest energy-consuming sector, and the use of biomass is prevalent in its energy mix. The commercial sector is second at 6% followed by the transport sector at 4%. Since there are limited industries operating in the province, industrial energy consumption is at 2%. Although mechanization in the agricultural sector is gaining popularity, the use of fuel in this sector is very low at 1%. This can indicate that, for a country like Nepal, which has vast fertile lands, there could be ample opportunity for economic development through mechanization and renewable energy penetration in the agricultural sector.

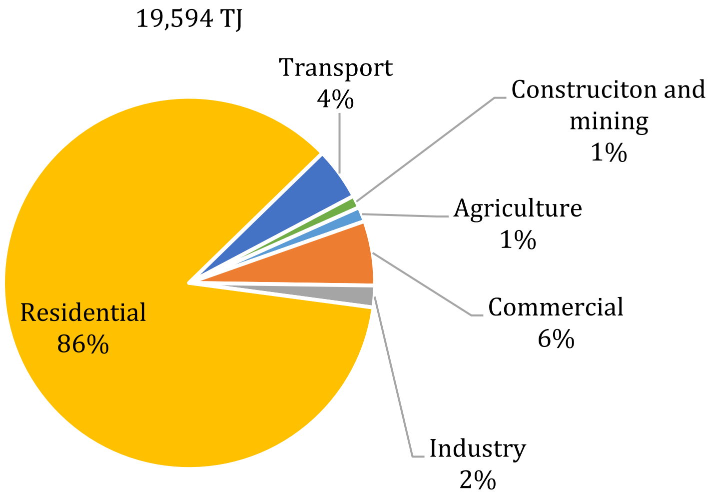


Figure 6-2. Energy Consumption by Sectors in Karnali Province

(Survey, 2022)

The energy mix by fuel in different sectors can be seen in **Table 6-1.** Unlike in other provinces, the major portion of the traditional biomass is consumed in the residential sector. Meanwhile, the use of agricultural residue and animal waste is very low – firstly due to the availability of commercial fuels, and secondly, animal wastes are used up for biogas and manure making. There are small amounts of agricultural residues seen to be used in industries for thermal purposes – mainly due to cheaper prices and local/regional availability. The residential sector has the highest use of electricity as well. However, the use of electricity in the commercial sector is significant but quite low – mainly due to the lesser number of industries. Meanwhile, petrol and diesel are used largely in transport for vehicles, with a considerable share of diesel consumption in the agriculture sector- for farm machinery and the industry sector – for power motives as well as thermal purposes. In addition to that, the industry also uses diesel for electricity generation using diesel generators. The heavy equipment in the construction and mining sector also seems to consumption a considerable amount of petroleum products in this province in comparison to other sectors, not just because this sector is highly active, but because other sectors are passive.

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

in TJ

	Renewables							Non-renewable							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	-	-	-	-	-	0.04	1.64	0.03	243.76	-	-	-	-	-	245.46
Commercial	633.10	9.49	5.54	-	-	339.02	56.41	-	-	0.02	-	-	60.07	0.52	1,104.16
Industry	86.68	8.45	-	-	-	-	18.06	35.53	158.08	17.50	-	-	0.99	48.07	373.35
Residential	16,332.00	21.65	-	3.33	0.23	26.62	140.78	-	-	0.78	-	-	241.83	0.08	16,767.30
Transport	-	-	-	-		-	0.03	280.86	469.96	-	-	139.95	-	-	890.80
Construction and mining	-	-	-	-		-	1.76	8.88	199.02	-	-	-	3.66	-	213.32
Total	**17,051.78**	**39.58**	**5.54**	**3.33**	**0.23**	**365.68**	**218.68**	**325.30**	**1,070.81**	**18.30**	**-**	**139.95**	**306.54**	**48.67**	**19,594.39**

(Survey, 2022)

Figure 6-3 illustrates the flow of the energy in the Karnali Province. It is quite visible that the largest shares of energy are from primary solid biomass followed by petroleum products in 2022 and mostly are consumed by residential sectors. It is also clear that the province needs to push economic activities for economic development.

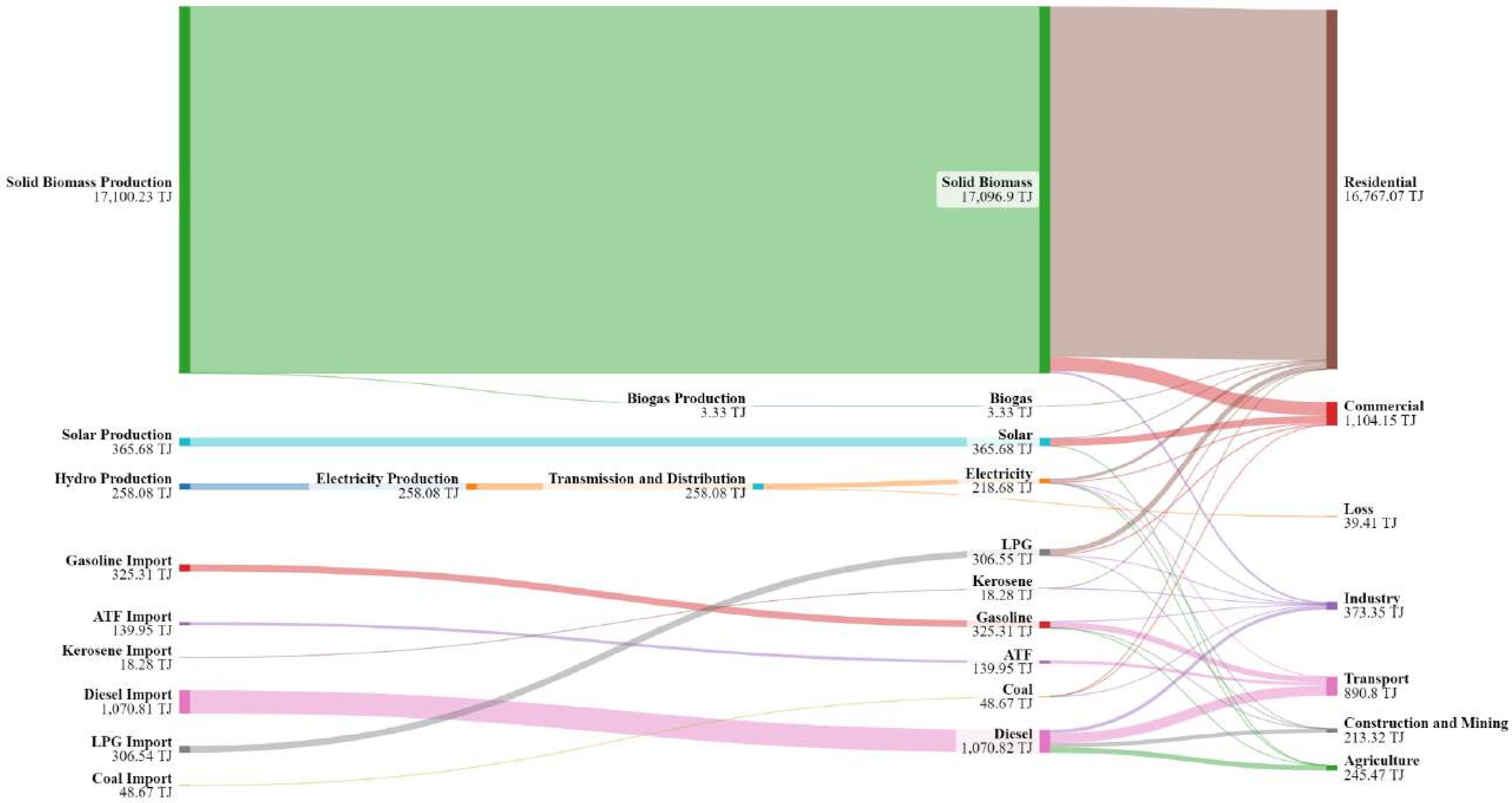


Figure 6-3. Energy Flow in Karnali Province (Sankey Diagram)

Table 6-2 shows the energy consumption indicators for Karnali Province. The energy intensities very less in this province as there is limited economic activities on the other. The electricity consumption per capita also comes far less than the national average as the grid electricity is mostly used only for lighting purposes due to poor household connections along with the lower economic status to shift to new technologies. The residential electricity consumption per household is way behind the tier-5 level of 3,000 kWh (World Bank/ESMAP, 2015).

Table 6-2. Energy Consumption Indicators

Parameter	Unit (per annum)	Value
Energy per capita	GJ per capita	11.61
Energy per GVA	GJ per million NRs	114
Share of modern and new renewable energy		3%
Electricity Consumption (Total)	kWh per capita	96
Electricity Consumption (Residential)	kWh per HH	109

(Survey, 2022)

6.1 Energy Consumption in Karnali Province by Ecological Regions

The ecological distribution of energy consumption is affected by population, as well as energy access. The province consists only of two ecological regions- mountain and hilly. As seen in **Table 6-3.** The mountain region has the least amount of energy consumed – primarily due to the least number of people in the region. The hilly region consumed a large share of energy as the region inhabits most of the population. Also, most of the economic activities are concentrated in this region due to access to good services. In terms of energy types as well, the use of traditional biomass is dominant in hilly regions, even though biomass share is significant in the mountains. Meanwhile, commercial fuels such as petroleum products and electricity are highly used in the hilly region. Sector-wise, energy consumption is yet again influenced by population and the presence of economic activity. And hence, the energy consumption share is high in hilly regions with more than 60% consumption in the residential sector.

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

In TJ

		Fuelwood	**Agri residue**	**Animal waste**	**Coal**	**Kerosene**	**LPG**	**Diesel**	**Gasoline**	**ATF**	**Furnace oil**	**Electricity**	**biogas**	**briquettes**	**Solar thermal**	**Solar PV**	**Total**
Mountain		**5,212.67**	**11.46**	**5.54**	**0.58**	**0.02**	**61.87**	**12.39**	**35.53**	-	-	**11.77**	-	-	-	**185.19**	**5,537.03**
	Agriculture	-	-	-	-	-	-	11.49	-	-	-	0.05				0.02	**11.56**
	Commercial	423.37	9.49	5.54	0.49	0.02	23.09	-	-	-	-	3.45	-	-	-	178.49	**643.93**
	Industrial	32.78	-	-	-	-	0.06	0.90	35.53	-	-	0.28	-	-	-	-	**69.55**
	Residential	4,756.53	1.98	-	0.08	-	38.72	-	-	-	-	8.00	-	-	-	6.68	**4,811.98**
Hills		**11,839.11**	**28.12**	-	**48.09**	**18.28**	**241.01**	**389.44**	**0.03**	-	-	**205.11**	**3.33**	**0.23**	**0.00**	**180.49**	**12,953.23**
	Agriculture	-	-	-	-	-	-	232.27	0.03	-	-	1.58	-	-	-	0.02	**233.90**
	Commercial	209.73	-	-	0.02	-	36.98	-	-	-	-	52.96	-	-	0.00	160.53	**460.23**
	Industrial	53.90	8.45		48.07	17.50	0.92	157.18	-	-	-	17.78	-	-	-	-	**`303.79**
	Residential	11,575.48	19.67	-	-	0.78	203.11	-	-	-	-	132.78	3.33	0.23	-	19.94	**11,955.31**
Terai																	
	Agriculture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Commercial	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Industrial	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Province										-	-						
	Transport	-	-	-	-	-	-	469.96	280.86	139.95	-	-	-	-	-	-	**890.77**
	Construction and mining	-	-	-	-	-	3.66	199.02	8.88	-	-	1.76	-	-	-	-	**213.32**
Grand total		**17,051.78**	**39.58**	**5.54**	**48.67**	**18.30**	**306.54**	**1,070.81**	**325.30**	**139.95**	-	**218.64**	**3.33**	**0.23**	**0.00**	**365.68**	**19,594.35**

(Survey, 2022)

6.2 Agriculture Sector

The agriculture sector in Karnali Province only consumes about 245 TJ which is about 1.3% of the total energy consumed in the province and among these, the use of diesel for farm machinery is very high in comparison to the consumption of petrol and electricity (**Figure 6-4**). Although the penetration of solar pumping systems for irrigation is gaining popularity, adding to the limited agricultural activity and mechanization, its use has been limited. It is mainly due to geographical difficulties in hilly and mountainous regions.

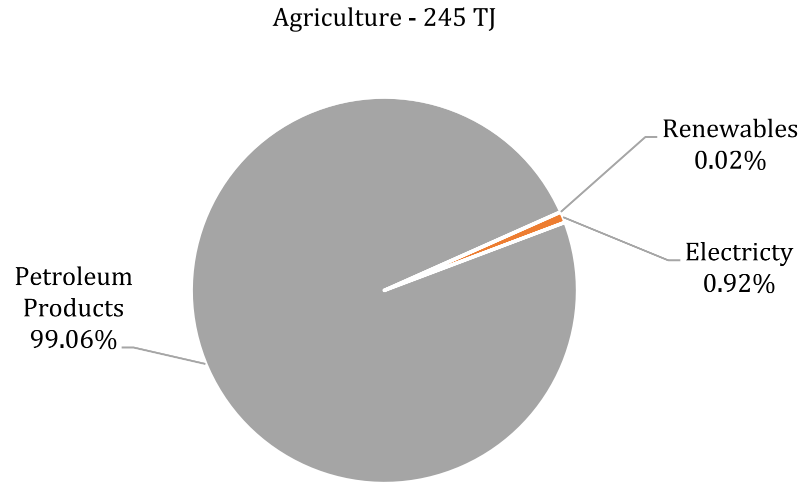


Figure 6-4. Energy Mix in Agriculture Sector

From **Table 6-4** most of the diesel is used for farm machinery. A large portion of irrigation in Karnali Province is dependent upon ground and rainwater. Meanwhile, electricity is mostly used for water pumping and very less electricity is used 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 mountainous regions.

Table 6-4. Energy Consumptions in Agriculture Sector

In TJ

	Water pumping	Tilling	Threshing	Total
Petrol	-	-	0.03	**0.03**
Diesel	12.59	136.05	95.12	**243.76**
Electricity	1.64	0.00	0.00	**1.64**
Solar	0.04	-	-	**0.04**
	14.26	**136.05**	**95.15**	**245.46**

Ecologically, the largest amount of energy is consumed in the hilly region for all purposes **(Table 6-5)** In contrast to hills and mountain regions, irrigation is largely done by diesel pumps. Meanwhile, the upper regions, being more dependent upon ground and rainwater, use less energy for irrigation. Tillage is equally important and thus is done by diesel tractors in both hilly and terai regions. As crops are majorly planted in the terai area, energy used for threshing is also high in the same region.

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

In TJ

	Petrol	Diesel	Electricity	Solar	
Mountain	-	11.49	0.05	0.02	**11.56**
Hills	0.03	232.27	1.58	0.02	**233.90**
Total	**0.03**	**243.76**	**1.64**	**0.04**	**245.46**

6.3 Commercial Sector

The commercial sector is the second most energy-consuming sector, at 1,104 TJ. Although the commercial sector is expected to use commercial forms of energy, the use of biomass is still prevailing in this sector in Karnali Province (59%) followed by renewables (31%) which is mainly solar PV (**Figure 6-5**). Biomass is used primarily in hotels and restaurants, barracks, and community centers for cooking and water heating purposes. Some portions of biomass are specifically used for space heating in colder seasons as well. Most electricity is used for electrical appliances, lighting, cooling, and some cooking purposes.

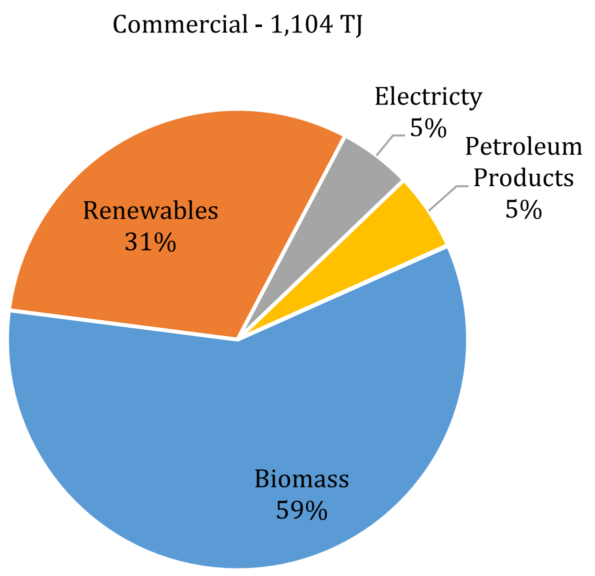


Figure 6-5. Energy Mix in Commercial Sector

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, but the use of solar PV is significant for electrical appliances as well as for lighting due to poor access to grid electricity as well as the successful promotion of renewable energy technologies in remote areas.

Table 6-6. Energy Consumption in Commercial Sector

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	Other use	
Fuelwood	632.51	0.57	0.02	-	-	-	-	-	**633.10**
Agricultural residue	9.49	-	-	-	-	-	-	-	**9.49**
Animal waste	5.54	-	-	-	-	-	-	-	**5.54**
Coal	0.52	-	-	-	-	-	-	-	**0.52**
Kerosene	0.02	-	-	-	-	-	-	-	**0.02**
LPG	55.81	1.24	3.01	-	-	-	-	-	**60.07**
Electricity	0.60	0.29	0.04	1.36	6.24	47.88	-	-	**56.41**
Solar thermal	-	0.00	-	-	-	-	-	-	**0.00**
Solar PV	-	-	-	-	35.22	303.80	-	-	**339.02**
Total	**704.49**	**2.11**	**3.07**	**1.36**	**41.46**	**351.68**	**-**	**-**	**1,104.16**

Subsector-wise, the largest amount of energy is used in the social sector which comprises hospitals, schools, and offices. It uses solar PV as the major source for lighting and electrical appliances. On the other hand, accommodation and food services also use a considerable amount of energy and 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
Fuelwood	266.20	271.83	1.45	86.25	7.36	**633.10**
Agricultural residue	9.35	0.14	-	-	-	**9.49**
Animal waste	5.35	0.19	-	-	-	**5.54**
Coal	0.48	0.03	-	-	-	**0.52**
kerosene	0.02	-	-	-	-	**0.02**
LPG	10.46	27.66	2.36	12.00	7.59	**60.07**
Diesel	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	**-**
Electricity	9.23	7.36	3.34	28.20	8.29	**56.41**
biogas	-	-	-	-	-	**-**
briquettes	-	-	-	-	-	**-**
Solar thermal	-	0.00	-	-	-	**0.00**
Solar PV	0.28	0.15	0.03	338.08	0.47	**339.02**
Total	**301.37**	**307.37**	**7.18**	**464.53**	**23.71**	**1,104.16**

As for energy-using activities in sub-sectors, the highest amount of energy is used for cooking **(Table 6-8)**, with the majority in biomass as seen in **Table 6-6 and Table 6-7**. Water heating is largely used by accommodation service institutions and space heating is used in financial and social sectors.

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	291.98	0.01	0.07	0.69	3.41	5.21	-	-	**301.37**
Accommodation	298.95	1.41	0.01	0.08	1.34	5.58	-	-	**307.37**
Financial	2.25	0.01	1.60	0.01	0.31	3.00	-	-	**7.18**
Social	96.48	0.66	1.20	0.41	35.42	330.36	-	-	**464.53**
Others	14.83	0.01	0.20	0.16	0.98	7.53	-	-	**23.71**
Total	**704.49**	**2.11**	**3.07**	**1.36**	**41.46**	**351.68**	**-**	**-**	**1,104.16**

Ecologically, the mountain region consumes a larger portion of energy in the commercial sector due to high consumption by inefficient technologies using fuelwood, agriculture residue and animal waste in cooking and space heating and due to prevalence of solar Home Systems (SHS) for lighting purposes in accommodation and trade and retail sub-sectors **(Table 6-9 and Table 6-10).** Although most of the high-intensity energy use is in hilly regions, the mountain region being a colder area, the energy for space heating is mostly used in the upper mountains.

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	
Mountain	459.04	0.01	3.02	-	20.02	161.84	-	**643.93**
Hills	245.45	2.09	0.04	1.36	21.44	189.84	-	**460.23**
Total	**704.49**	**2.11**	**3.07**	**1.36**	**41.46**	**351.68**		**1,104.16**

Table 6-10 indicates that fuel-wise also, a higher quantity of energy is used in the mountain region. Solar Home Systems (HS) are also used for lighting purposes in hilly regions. Meanwhile, in mountain regions, the use of LPG is less, but biomass is used in large quantities.

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

	Fuelwood	Agricultural residue	Animal waste	Coal	Kerosene	LPG	Electricity	Solar PV	
Mountain	423.37	9.49	5.54	0.49	0.02	23.09	3.45	178.49	**643.93**
Hills	209.73	-	-	0.02	-	36.98	52.96	160.53	**460.23**
Total	**633.10**	**9.49**	**5.54**	**0.52**	**0.02**	**60.07**	**56.41**	**339.02**	**1,104.16**

6.4 Residential Sector

The residential sector is the highest energy-consuming sector in the Karnali Province with a total of 16,767 TJ. This sums to nearly 86% of the total energy consumed in the province, the main reason being the use of inefficient energy usage patterns and technologies. In the energy mix, the use of biomass is dominant in this province (98%) followed by petroleum products mainly LPG and electricity (**Figure 6-6**). The use of electricity is not able to take a higher share, majorly due to the problem of access via the grid as well as the power supply reliability issues.

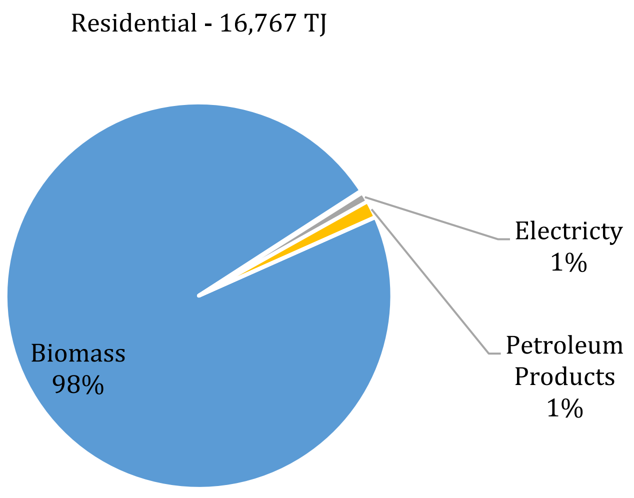


Figure 6-6. Energy Mix in Residential Sector

Table 6-11 gives the energy mix for various end-use activities versus the type of fuel used in the residential sector. It can be observed that biomass is primarily consumed for cooking. LPG is also mostly used for cooking purposes. Though electricity is used majorly for electrical appliances and lighting, its use for cooking purposes is also quite measurable. It is a positive sign towards electrification and clean energy usage. However, the current use of traditional biomass and LPG shows significant efforts required for the energy transition to clean energy sources.

Table 6-11. Energy Consumptions in Residential Sector

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	16,210.19	8.38	1.30	-	-	-	112.13	**16,332.00**
Agricultural residue	21.65	-	-	-	-	-	-	**21.65**
Animal waste	-	-	-	-	-	-	-	**-**
Coal	0.08	-	-	-	-	-	-	**0.08**
Kerosene	-	-	-	-	-	-	0.78	**0.78**
LPG	236.67	2.08	3.08	-	-	-	-	**241.83**
Electricity	20.92	-	0.05	3.77	22.65	93.38	-	**140.78**
Biogas	3.33	-	-	-	-	-	-	**3.33**
Briquettes	-	-	0.23	-	-	-	-	**0.23**
Solar thermal	-	-	-	-	-	-	-	**-**
Solar PV	-	-	-	-	26.62	-	-	**26.62**
Total	**16,492.84**	**10.46**	**4.66**	**3.77**	**49.27**	**93.38**	**112.90**	**16,767.30**

Although the population is lower in rural municipalities, the amount of energy used is comparatively higher in rural areas (**Table 6-12 and Table 6-13**). This is due to the use of inefficient technologies in rural areas. 99% of energy is used in the form of traditional biomass for cooking in rural areas. The use of electrical appliances is also lower in comparison to urban areas. However, the use of solar PV is almost equal to grid electricity for lighting in rural areas indicating the dissemination of renewable energy to most of the province through various government and non-governmental projects.

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

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	9,640.48	-	-	-	-	-	35.50	**9,675.98**
Agricultural residue	10.43	-	-	-	-	-	-	**10.43**
Animal waste	-	-	-	-	-	-	-	**-**
Coal	0.08	-	-	-	-	-	-	**0.08**
Kerosene	-	-	-	-	-	-	-	**-**
LPG	72.96	-	-	-	-	-	-	**72.96**
Electricity	0.19	-	-	0.42	8.95	14.69	-	**24.25**
Solar PV	-	-	-	-	21.40	-	-	**21.40**
Total	**9,724.14**	**-**	**-**	**0.42**	**30.35**	**14.69**	**35.50**	**9,805.10**

In comparison to rural areas, the urban area is slightly more dependent upon commercial forms of energy, but not as high in comparison to other provinces. Although the share of biomass is still predominant in urban regions as well, the consumption of LPG and electricity is also not significant. The use of solar PV in urban areas is, however, lower compared to the rural areas due to the access to grid electricity.

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

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	6,569.71	8.38	1.30	-	-	-	76.63	**6,656.02**
Agricultural residue	11.22	-	-	-	-	-	-	**11.22**
Animal waste	-	-	-	-	-	-	-	**-**
Coal	-	-	-	-	-	-	-	**-**
Kerosene	-	-	-	-	-	-	0.78	**0.78**
LPG	163.71	2.08	3.08	-	-	-	-	**168.87**
Electricity	20.74	-	0.05	3.35	13.71	78.69	-	**116.53**
Biogas	3.33	-	-	-	-	-	-	**3.33**
Briquettes	-	-	0.23	-	-	-	-	**0.23**
Solar thermal	-	-	-	-	-	-	-	**-**
Solar PV	-	-	-	-	5.22	-	-	**5.22**
Total	**6,768.70**	**10.46**	**4.66**	**3.35**	**18.93**	**78.69**	**77.40**	**6,962.19**

The ecological distribution of energy consumption in the residential sector is highly influenced by the population distribution as seen in **Table 6-14** and **Table 6-15**. Particularly, the hilly region uses a significant amount of energy for cooking purposes. Space heating is done more in the colder mountainous region than in the hills.

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

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Other uses	In TJ
Mountain	4,712.50	-	4.38	-	10.50	4.18	80.43	**4,811.98**
Hills	11,780.34	10.46	0.28	3.77	38.77	89.20	32.48	**11,955.31**
Total	**16,492.84**	**10.46**	**4.66**	**3.77**	**49.27**	**93.38**	**112.90**	**16,767.30**

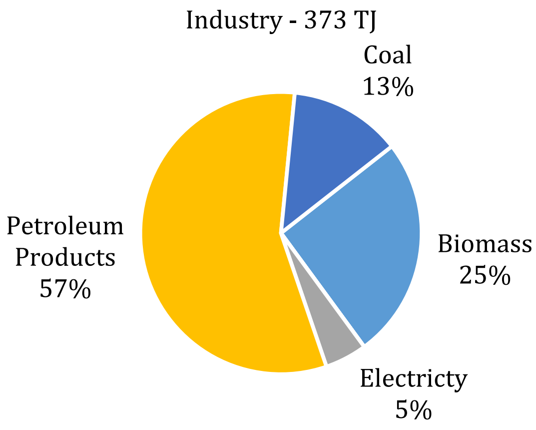
In terms of energy type, it is observed that the hilly region is predominantly using biomass as well as other forms of energy. A large amount of energy is seen to be used in the Salyan and Surkhet districts, comparatively more urbanized areas, of the hilly region.

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

	Fuelwood	Agriculture residue	Coal	Kerosene	LPG	Electricity	biogas	Briquettes	Solar PV	In TJ
Mountain	4,756.53	1.98	0.08	-	38.72	8.00	-	-	6.68	**4,811.98**
Hills	11,575.48	19.67	-	0.78	203.11	132.78	3.33	0.23	19.94	**11,955.31**
Total	**16,332.00**	**21.65**	**0.08**	**0.78**	**241.83**	**140.78**	**3.33**	**0.23**	**26.62**	**16,767.30**

6.5 Industrial Sector

The industrial sector consumed 373 TJ of energy in Karnali Province. This is very low in comparison to the national average as the number of large industries and even medium and small industries are comparatively very low in Karnali Province. The energy mix in the industrial sector is shown in **Figure 6-7.** Petroleum products, mainly diesel, are the major source of fuels used for thermal purposes as well as in diesel generators for electricity generation and motive power. On the other hand, fuelwood is also used significantly for heating purposes in food and beverage, and wood products and paper industries. Coal is mainly consumed in the brick and cement industries. With the gradual shift to clean energy, electricity usage has increased to some extent in industries reaching 5% of the total energy consumption in the industry sector.



(Survey, 2022)

Figure 6-7. Energy Mix in Industrial Sector

Table 6-16 shows the consumption of energy types for different end uses. It clearly indicates the highest use of energy in motive power and secondly for thermal purposes for which traditional biomass, furnace oil, coal, and diesel are the major sources. Diesel is 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 electrical motors and equipment.

Table 6-16. Energy Consumption in Industry Sector

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total in TJ
Fuelwood	-	17.49	54.95	-	14.24	**86.68**
Agri residue	-	8.45	-	-	-	**8.45**
Coal	-	-	22.62	-	25.45	**48.07**
kerosene	-	-	17.50	-	-	**17.50**
LPG	-	0.06	0.92	-	-	**0.99**
Diesel	-	-	9.00	112.90	36.18	**158.08**
Gasoline	-	-	-	35.53	-	**35.53**
Furnace oil	-	-	-	-	-	**-**
Electricity	0.45	0.48	0.38	16.73	0.01	**18.06**
Total	**0.45**	**26.49**	**105.37**	**165.16**	**75.88**	**373.35**

(Survey 2022)

All the manufacturing industries mentioned in Nepal Standard Industrial Classification are grouped into 9 sub-sectors based on their energy intensity and product type. The energy consumption based on its sub-sectors is shown in **Table 6-17.** Food and beverage industries, wood products and paper industries, cement and non-metallic industries, chemical rubber and plastics, and mechanical engineering industries consumed comparatively higher energy at 30%, 22%, 19%, 15%, and 13% respectively. They consumed diesel, fuelwood, and gasoline as their major sources of energy.

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

	Fuelwood	Agricultural residue	Coal	Kerosene	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Food Beverage and Tobacco	31.07	-	-	-	-	70.20	-	-	10.63	**111.90**
Textile and Leather Goods	0.01	-	-	-	-	-	-	-	0.00	**0.01**
Chemical Rubber and Plastic	-	-	-	-	-	56.16	-	-	0.19	**56.35**
Mechanical Engineering and Manufacturing	-	-	-	17.50	-	28.66	0.33	-	1.81	**48.30**
Electrical Engineering Products	-	-	-	-	-	-	-	-	-	-
Wood Products and Paper	43.60	-	-	-	0.06	0.72	35.21	-	3.03	**82.62**
Bricks & Structural Clay Products	-	-	-	-	-	-	-	-	0.19	**0.19**
Cement & Nonmetallic Products	11.94	8.45	48.07	-	0.92	-	-	-	0.37	**69.74**
Other Manufacturing	0.07	-	-	-	-	2.34	-	-	1.83	**4.23**
Total	**86.68**	**8.45**	**48.07**	**17.50**	**0.99**	**158.08**	**35.53**	**-**	**18.06**	**373.35**

(Survey 2022)

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 20% of total energy consumption in the sector. Diesel is mainly used for motive power due to lack of continuous flow of electricity in the province. The major energy-consuming industries in Karnali Province are the food and beverage industries.

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

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Food Beverage and Tobacco	0.05	16.90	9.38	45.30	40.27	**111.90**
Textile and Leather Goods	0.00	-	0.01	-	-	**0.01**
Chemical Rubber and Plastic	0.02	-	-	46.97	9.36	**56.35**
Mechanical Engineering and Manufacturing	0.06	-	17.50	30.74	-	**48.30**
Electrical Engineering Products	-	-	-	-	-	**-**
Wood Products and Paper	0.08	0.21	43.60	38.00	0.72	**82.62**
Bricks & Structural Clay Products	0.17	-	-	0.02	-	**0.19**
Cement and Non-metallic Products	0.03	9.38	34.88	-	25.45	**69.74**
Other Manufacturing	0.04	-	-	4.12	0.07	**4.23**
Total	**0.45**	**26.49**	**105.37**	**165.16**	**75.88**	**373.35**

(Survey 2022)

Table 6-19 shows fuel-wise energy consumption by ecological region in Karnali Province. Since it consists of only mountains and hills, there is approximately 81% of the consumption in the Hilly region, and the remaining 19% is consumed in the mountainous region. Surkhet is the major energy-consuming district of the province with industrial energy consumption of 58% of total consumption in the province. Motive power and process heat are two end uses consuming a large share of energy 28%

and 44% respectively. A large share of energy is also used for power generation from diesel generators.

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

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Mountain	0.04	0.21	32.71	35.63	0.97	**69.55**
Hills	0.42	26.28	72.66	129.54	74.91	**303.79**
Total	**0.45**	**26.49**	**105.37**	**165.16**	**75.88**	**373.35**

(Survey 2022)

Fuel-wise, traditional biomass, coal, diesel, furnace oil, gasoline, and electricity are mostly consumed in hilly regions. Diesel is the major fuel source consumed in hilly regions mostly in food and beverage industries, mechanical engineering, and manufacturing industries. Diesel is used both for thermal purposes and electricity generation from diesel generators. On the other hand, agri-residue and fuelwood are particularly used in food and beverage industries for boilers and process heating **(Table 6-20).**

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

	Fuelwood	Agri residue	Coal	Kerosene	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Mountain	32.78	-	-	-	0.06	0.90	35.53	-	0.28	**69.55**
Hills	53.90	8.45	48.07	17.50	0.92	157.18	-	-	17.78	**303.79**
Total	**86.68**	**8.45**	**48.07**	**17.50**	**0.99**	**158.08**	**35.53**	**-**	**18.06**	**373.35**

(Survey 2022)

A huge amount of heat energy is obtained from fossil fuels – primarily from diesel, coal, and furnace oil. Generators for electricity still consume a large quantity of diesel in the industry as the electricity supply is not adequately reliable. Batch production in industries like food and beverage production requires a reliable electricity supply from the grid. Diesel is also being used for thermal uses in addition to using motive power because of their lower impact, mainly on food products, in place of furnace oils. The grid electricity consumption share, however, is only 5% of energy consumption in industries in Karnali 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 the industrial sector could be in using electric furnaces and heaters for thermal purposes – while electricity is generated from hydropower plants in the country, replacing the need for decentralized generators operating on imported fossil fuels.

There are positive signs of an energy transition to clean energy even in the industrial sector which were not there a couple of years ago. In the food and beverage industry subsector, the industry management is still relying on rice husk and fuelwood for boilers even though electric boilers are 25% cheaper but they showed enthusiasm to switching to electricity provided the supply is reliable and without interruption. 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 and reliability of supply can be expected soon.

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

Road transport dominates all modes of transport in Nepal. There are three international airports in Nepal, among which only one of them is in full operation. Water transport is not yet popular in Nepal. But cable transport like cable cars, ropeways, and twin crossings are still in use in many parts of Nepal. In this energy consumption survey, for Karnali 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, motorcycle, etc.	Passenger/Freight
LPG	Tempo	Passenger
Electric	Rickshaw	Passenger

Aviation

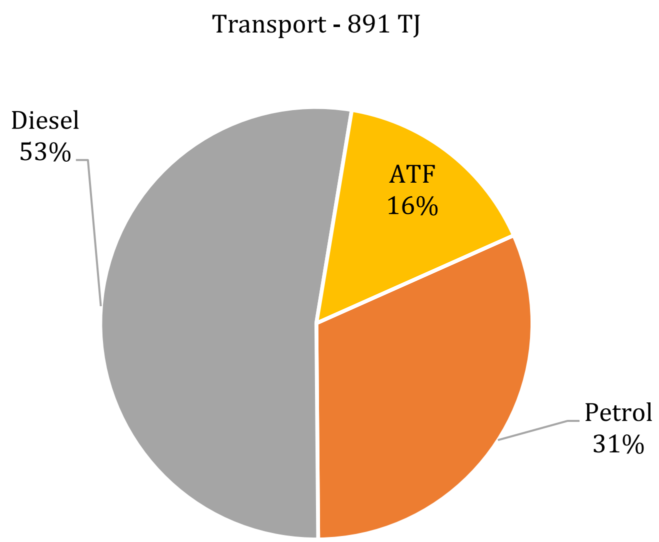
There are two airports in operation where domestic flights take place. The data regarding aircraft are published by the Civil Aviation Authority of Nepal (CAAN). The data shows the total aircraft movement, passenger movement and cargo movement as given in **Table 6-22.**

Table 6-22. Aviation Sector Activity (CAAN, 2020; CAAN, 2020a)

	Aircraft movement	Passenger movement	Cargo movement (in kg)
Dolpa	1,496	18,463	219,802
Jumla	1,318	16,947	58,631
Rara	2,116	19,950	207,829
Rukum Salle	192	2,310	-
Simikot, Humla	10,614	138,104	2,814,508
Surkhet	2,990	19,941	8,122,210
Chaurjahari, Rukum west	7,000	34,000	130,000
Karnali Province	**25,726**	**249,715**	**11,552,980**

6.6.1 Transport Sector Energy Consumption by Fuel Types

The transport sector consumed 891 TJ energy, which is 5% of the total provincial energy consumption. The energy mix in the transport sector is shown in **Figure 6-8.** It shows higher consumption of diesel as most of the public passenger vehicles and all of the freight vehicles are diesel operated and are also less energy efficient compared to private vehicles. The lower fuel economy in the hilly and mountainous road of Karnali Province leads to higher diesel and petrol consumption. In addition, due to poor road conditions, air traffic in the province is also significant as considerable amount of ATF is consumed.



(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 36%, that of private passenger vehicles is 37%, freight vehicle is 12%, and the remaining 16% by air transport. There are many intercity passenger- transport vehicles plying on the roads of the Karnali Province. In addition, domestic air transport is preferred due mainly to poor road conditions as well as longer travel time by local vehicles. The province has 7 airports to provide air transport facilities to the locals as well as tourists visiting the remote areas of Nepal.

Table 6-23. Total Transport Sector Energy Consumption by Subsector and Fuel Types (TJ)

Sub-sector		Diesel	Gasoline	ATF	Electric	
Public Passenger	Bus	117.65	-	-	-	117.65
	Microbus	76.94	-	-	-	76.94
	Minibus	61.22	-	-	-	61.22
	Tempo	60.99	-	-	-	60.99
	E rickshaw	-	-	-	0.03	0.03
Total		**316.8**	**316.80**	**-**	**0.03**	**316.83**
Private Passenger	Car	32.78	35.98	-	-	68.77
	Jeep	17.55	29.01	-	-	46.57
	Van	-	8.42	-	-	8.42
	Motorcycle	-	207.43	-	-	207.43
Total		**50.34**	**280.86**	139.95	**-**	**331.19**
Freight	Truck	5.93	-	-	-	5.93
	Mini Truck	31.47	-	-	-	31.47
	Tractor	44.04	-	-	-	44.04
	Pickup	21.38	-	-	-	21.38
Total		**102.82**	**280.86**	**-**	**-**	**102.82**
Aviation				**139.95**		
Grand Total		**469.96**	**280.86**	**139.95**	**0.03**	**890.8**[10]

(Survey 2022)

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 the fuel-efficient passenger carriers such as e-buses on one hand and on the other hand, it seems better that e-rickshaws are also substituting fuel-inefficient vehicles – i.e., motorcycles and cars. For these, there must be development in road infrastructure as well as this province has geographical difficulties.

6.7 Construction and Mining Sector

The construction and mining sector in Karnali used the least amount of energy among the six sectors at 213 TJ. 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 LPG. LPG is also used by on-site workers for heating purposes of bitumen for mixing with asphalt. There may be overlapping with energy consumption in the freight transport subsector as dumper trucks are widely used in the construction sector.

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

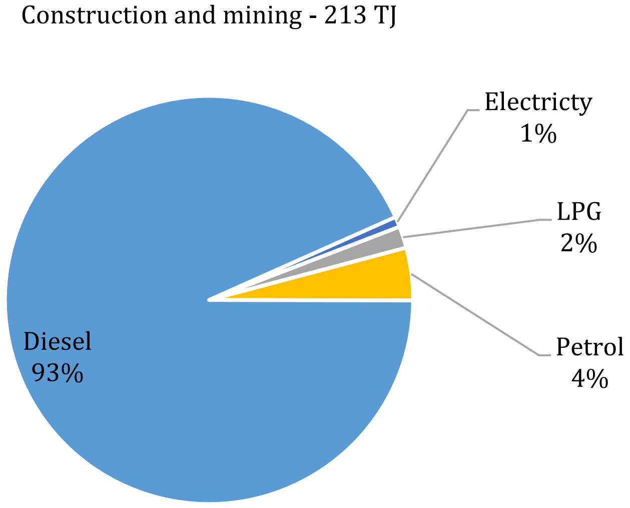


Figure 6-9. Energy Mix in Construction and Mining Sector

6.8 Fuel Demand by Time of Day

Fuel consumption or 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 residential sector, it can be seen in **Figure 6-10** that the usage of fuelwood starts as early as 5 AM and peaks between 6 to 9 AM. Its usage is low during daytime. However, it again peaks between 6 PM 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.

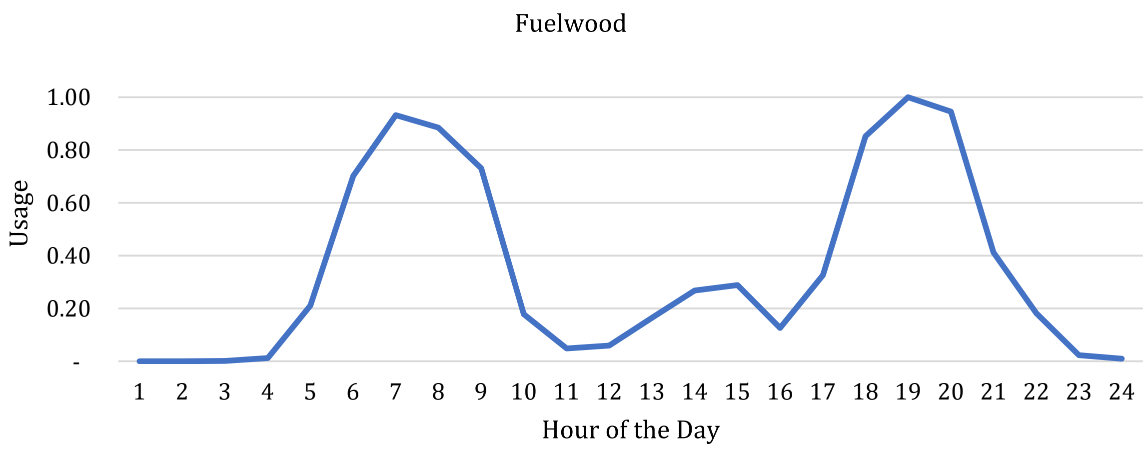


Figure 6-10. Energy Usage/Load Distribution Curve for Fuelwood in Residential Sector

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. Its usage again peaks during daytime, corresponding to afternoon snacks. Finally, it again peaks between 6PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals. The usage of LPG peaks differs than for fuelwood as these being easier to use, as well as due to lifestyle habits.

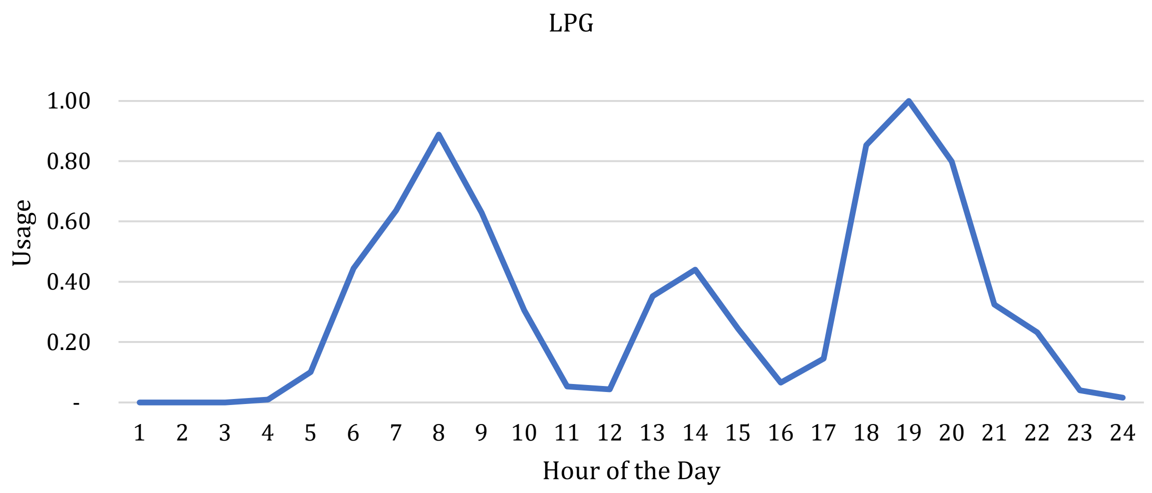


Figure 6-11. Energy Usage/Load Distribution Curve for LPG in Residential Sector

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 5AM to 7 AM. Its usage is comparatively lower during daytime. However, 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.

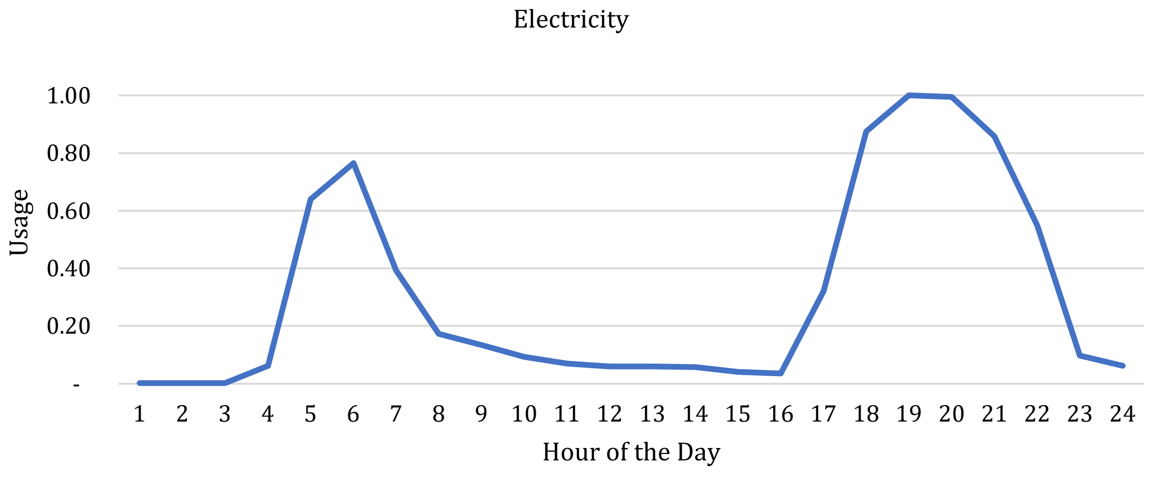


Figure 6-12. Energy Usage/Load Distribution Curve for Electricity in Residential Sector

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 between 6 AM to 8 AM. Its usage is low during daytime, though it peaks again at 2 PM to 3 PM during afternoon snacks time. 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.

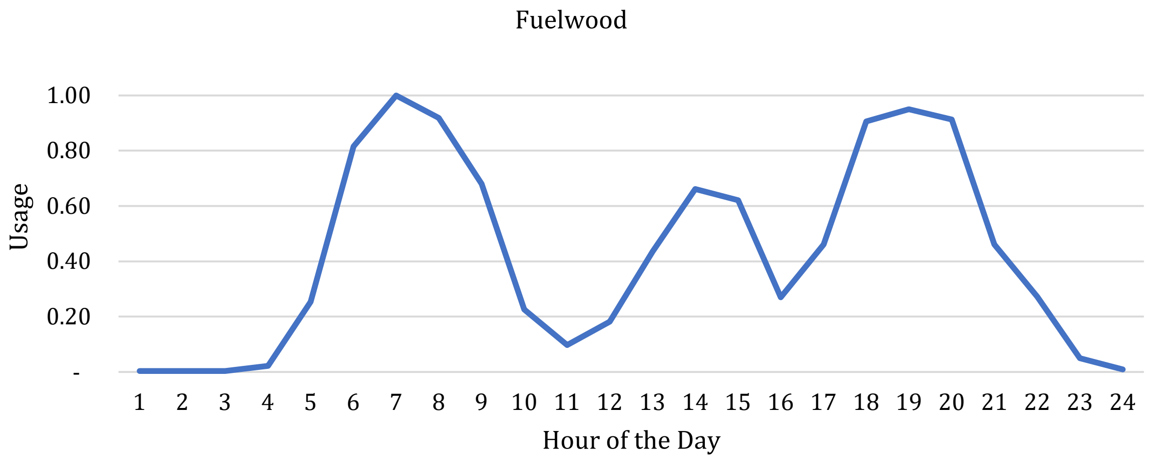


Figure 6-13. Energy Usage/Load Distribution Curve for Fuelwood in Commercial Sector

It can be seen in **Figure 6-**14 that the usage of LPG peaks at three spots of daytime. The LPG usage starts at 4 AM and first peaks at 7 AM to 8AM, during food preparation time. Its usage again peaks during daytime, corresponding to afternoon snacks. 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.

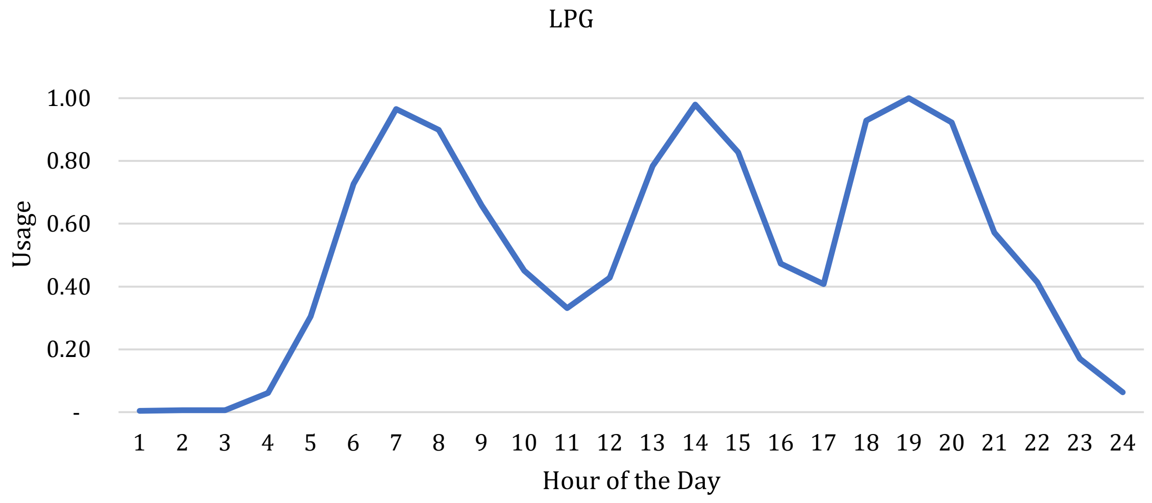


Figure 6-14. Energy Usage/Load Distribution Curve for LPG in Commercial Sector

The electricity uses in commercial uh sector starts at 4 AM, as seen from **Figure 6-15, when the** service activities slowly starts then it begins to rise up, peaks at 6 am. Usage remains constant during daytime, when the service activities are still going on including office activities and other commercial services. The major electricity usage peaks between 5 PM to 8 PM which is a highly active hour for services like hotels and restaurants, messes etc., as well as shops and others in commercial sector.

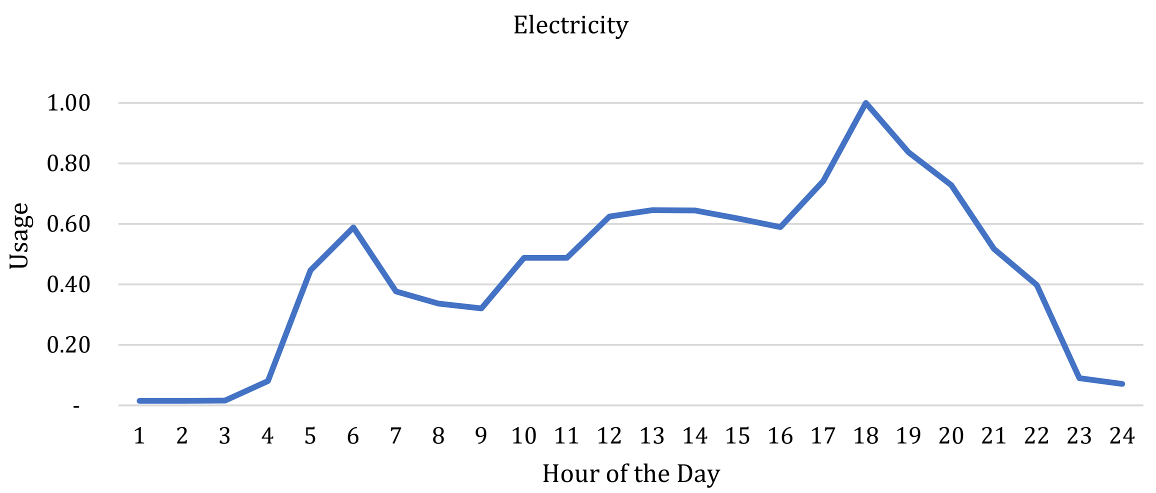
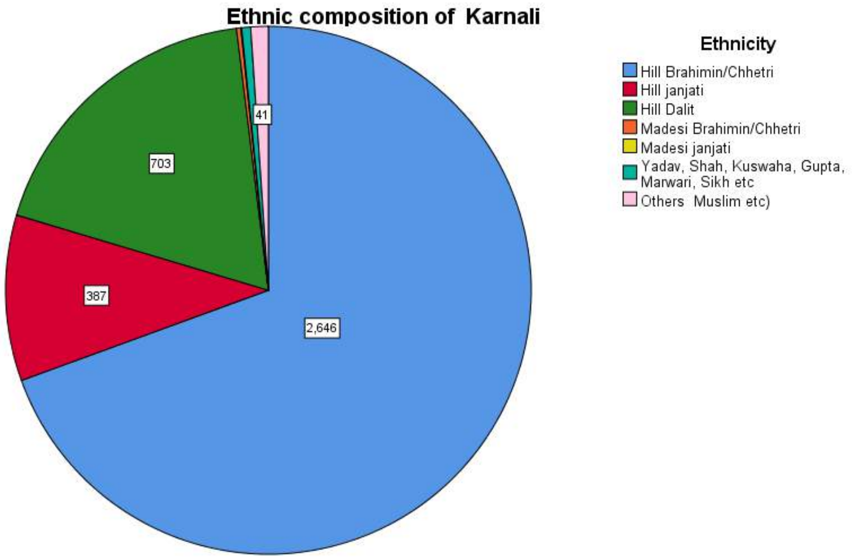


Figure 6-15. Energy Usage/Load Distribution Curve for Electricity in Commercial Sector

7 Socio-economic and Technical Analysis

7.1 Socio-economic Status

Karnali Province ranges from low hills to the mountains. Due to this, there is less variation in socio-economic characteristics than in other provinces. As shown in **Figure 7-1,** many respondents belong to hill Brahmin/Chhetri, followed by Hill Dalit, and Hill Janjati.



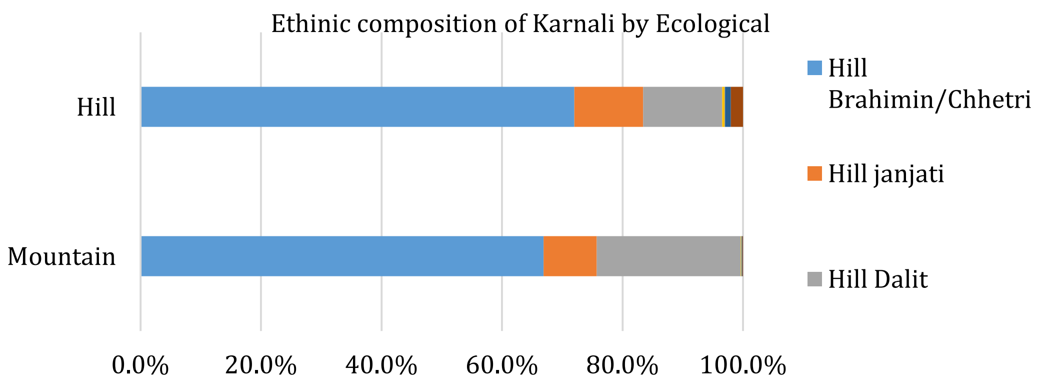


Figure 7-1: Mix of Respondents by Ethnic Group (top) and Ecological Regions (bottom)

It is evident that education level has an influence on decision-making. Thus, looking at the education level of household heads in this Province, it was seen that substantial household heads have no formal education followed by the partially literate. Nearly 31.89% of household heads do not have formal education **(Figure 7-2).** And the impact can be seen in the energy mix–fuelwood and other biomass still being predominant in the energy mix.

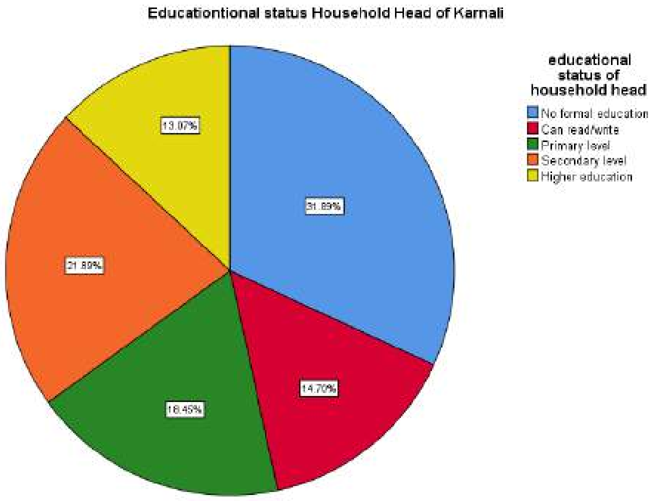


Figure 7-2: Mix of Respondents by Education Level of Household Head in Karnali Province

Another important aspect of socioeconomic behavior is 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. In the Mountain region nearly 38.65% of families have agriculture as their major source of income shown in **Figure 7-3.**

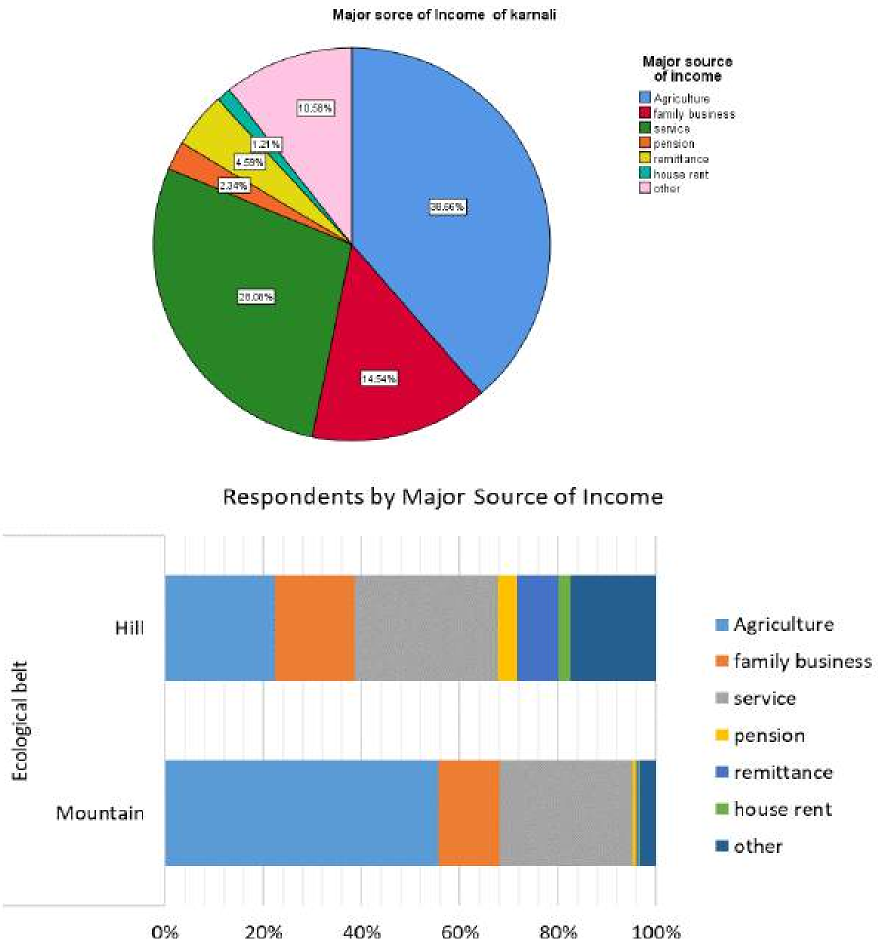


Figure 7-3: Mix of Respondents by Major Source of Income (top) and Ecological Regions (bottom)

The average monthly family income level ranges from as low as Rs 22,317.00 per month in households as per sample survey. This comes to an average of Rs 317,988 annual income per household in Karnali Province. This income level is lower with reference to the income level as per the National Living Standards survey Rs 30,121.00 per month (Fifth Household Budget Survey Nepal Rastra Bank 2014-2015). However, there is a huge variance from mean level of income in most of the cases which is evident from **Figure 7-4.**

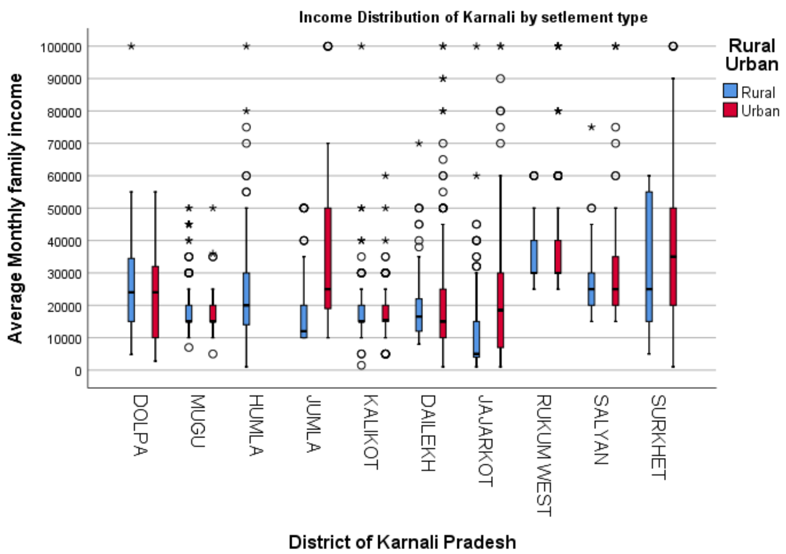


Figure 7-4: Average Monthly Income of Households

In Karnali Province, most 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).**

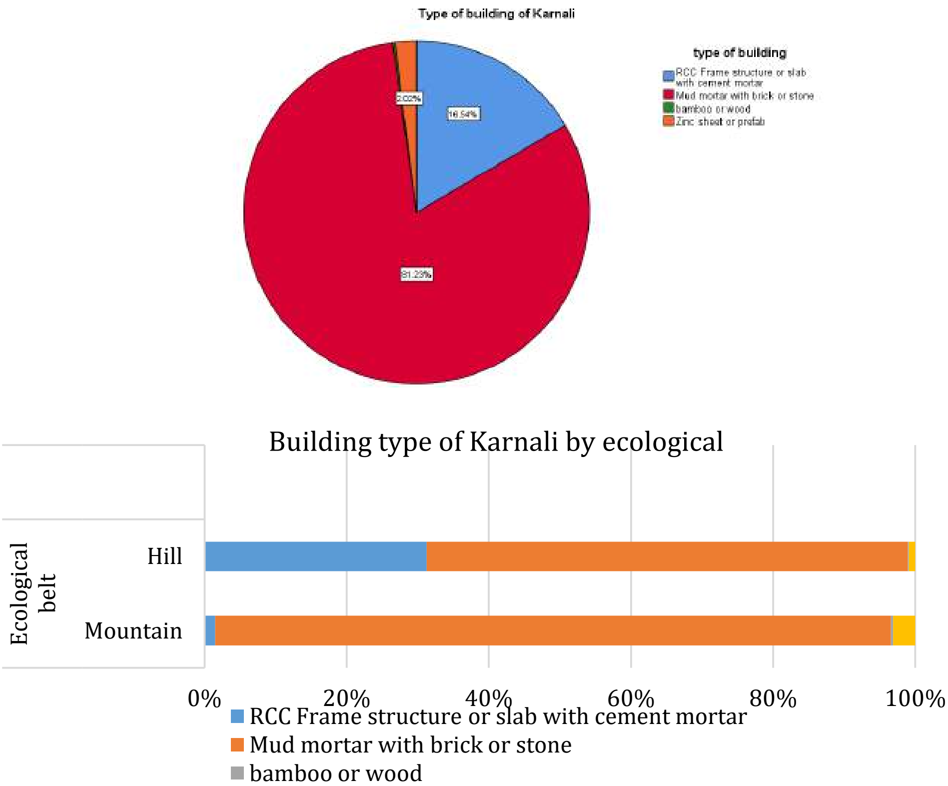


Figure 7-5: Mix of Respondent Household by Build Type (top) Ecological Regions (Bottom)

Meanwhile, for roofing structures, 53% households still used galvanized iron sheets or tiles or slates followed by RCC and then thatched roofs in older houses (**Figure 7-6**).

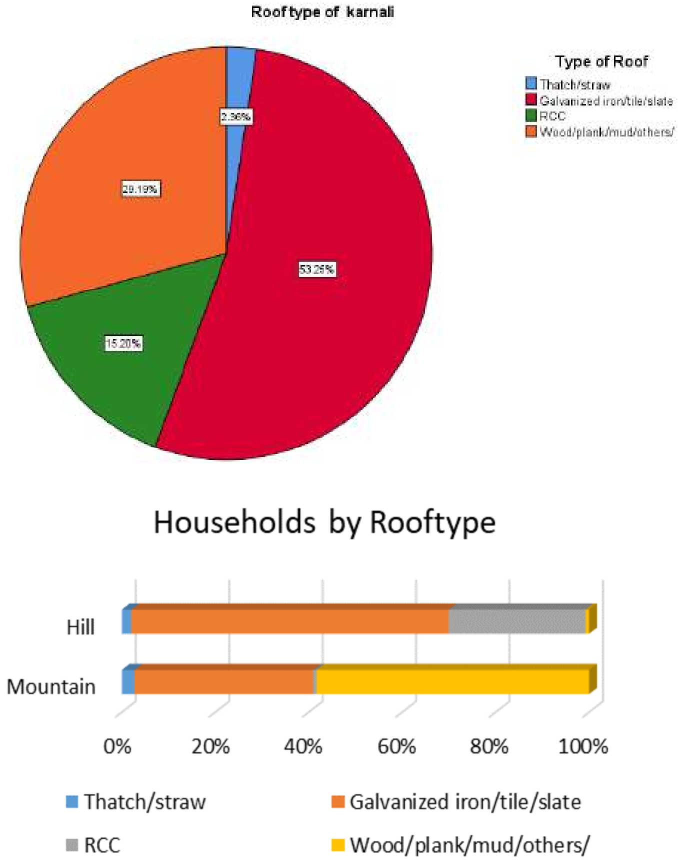


Figure 7-6: Mix of Respondent Households by Roof Type (top) and Ecological Regions (bottom)

7.2 Respondents by Gender

Figure 7-7 shows the mix of respondents and the respective household heads by gender. The male respondents are more than the female respondents and, there is majority in male being the household head. It can denote that the male is more involved in household related decisions as well as other activities. Furthermore, in rural areas, in households with female were hesitant or reluctant to give the information.

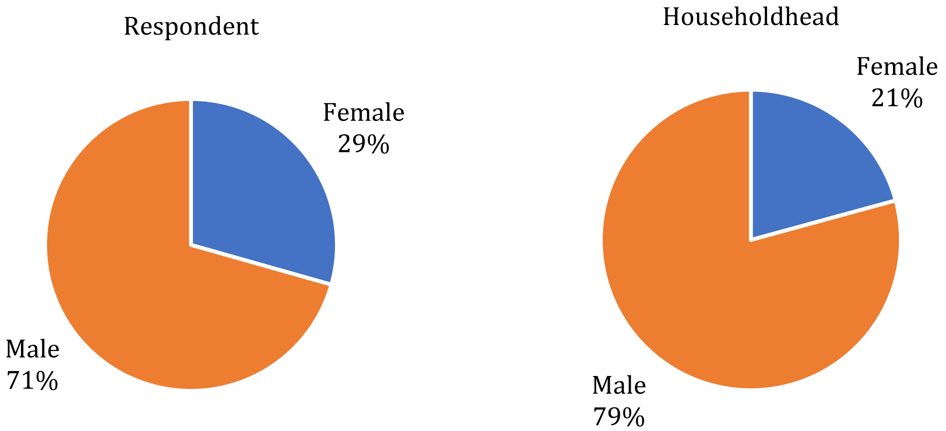
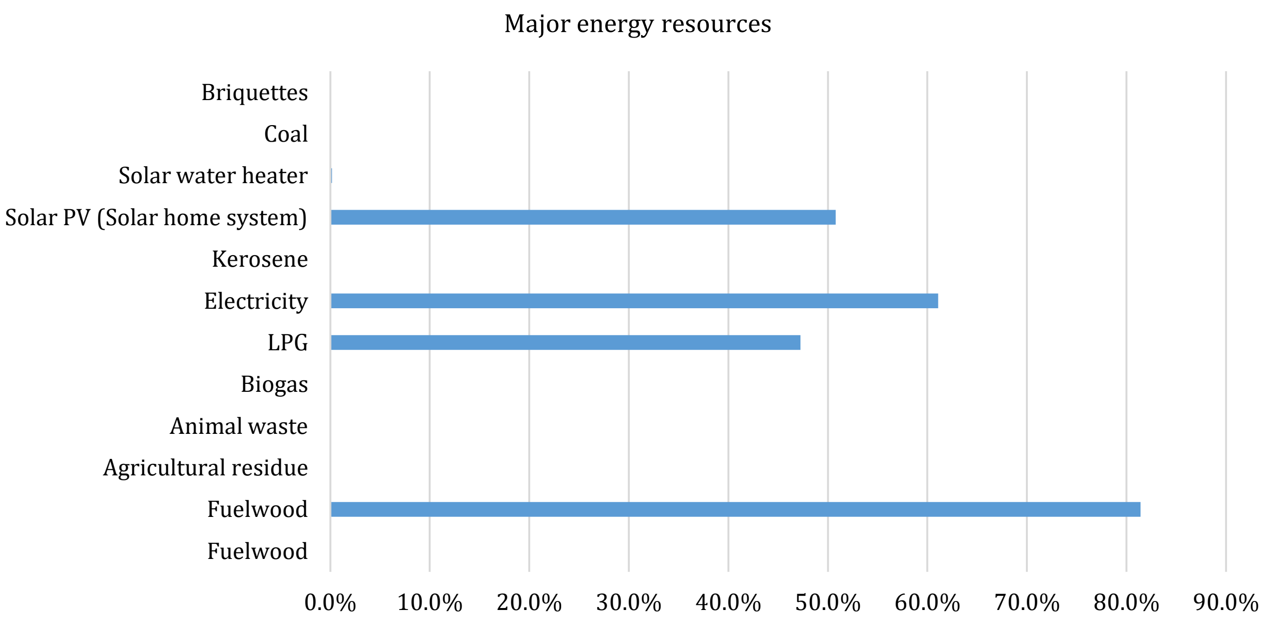


Figure 7-7: Mix of Household Respondents and the Household Head by Gender

7.3 Energy Access

Figure 7-8 shows the penetration of energy types in Karnali Province. Over 61% of the population has access to electricity. This energy mix shows that the society in Karnali Province is still in the phase of energy transition from traditional to modern fuels. As electricity is not sufficiently available, the consumption and use of fuelwood and other biomass is still high. This is since –traditional technology is very much energy inefficient requiring higher consumption and most importantly, these energy sources can be attained 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 Karnali, and it is normal practice in developing countries as consumers cannot depend on one source of energy due to affordability, fuel security, and traditional practices. The district-wise penetration of energy sources is given in **Annex**.



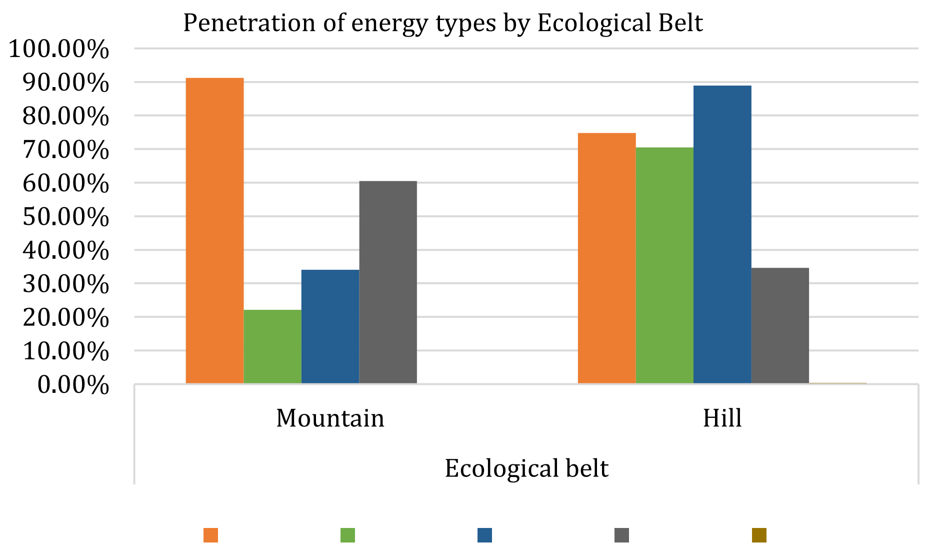


Figure 7-8: Penetration of Energy Types in Karnali (top) and Ecological Regions (bottom)

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. 415 per bhari (around 40 kg) on average, with the highest in Terai and the lowest in the mountains. Meanwhile the LPG in Koshi Province costs around NRs 2,003 per cylinder, with the transportation costs. It is seen that LPG is available at marked prices in accessible regions, however, it is much higher in costs in hills and in mountain regions due to transportation costs. Thus, the upfront cost of commercial energy still seems high. But if we take energy efficiency into consideration, the cost of useful energy would be much lower for commercial energy.

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

Average market price of fuel by type of Karnali

			Settlement	
		Karnali	Rural	Urban
	Unit	Mean	Mean	Mean
Fuelwood	Bhari (40kg)	415	411	415
LPG	cylinder	2003.1	2108.4	1969.3

		District wise Average market price of fuel by type									
	Unit	Dolpa	Mugu	Humla	Jumla	Kalikot	Dailekh	Jajarkot	Rukum west	Salyan	Surkhet
Fuelwood	Bhari (40kg)	500	380	418	1900	1000	314	362	346	435	321
LPG	1 cylinder	2,802.1	2,465.3	2,433.3	1,970.9	1,994.0	2,237.5	2,007.2	1,892.5	1,802.7	1,686.2

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.

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 were compared 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 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 below shows the total energy demand for the low growth case of various fuel types from base year to year 2050. The total energy demand in Karnali Province is expected to remain fairly constant from the current level of 19.6 PJ in 2022 to 20.5 PJ in 2030 and grow to 26 PJ in year 2050, with an average annual growth rate of only 1.05% per annum. Thus, the impact of low economic and demographic activities are clearly visible here in energy demand as well. Meanwhile the per capita energy demand is expected to grow from 11.8 GJ in 2022 to 12.8 GJ in 2050 in this scenario which also indicates that the energy consumption in future is going to increase but not as much as other economically developed regions.

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*	17.10	16.98	16.61	16.56	16.75	17.19	17.89
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.37	0.41	0.54	0.72	0.97	1.35	1.92
			Grid Electricity	0.22	0.27	0.32	0.38	0.47	0.59	0.78
Non-renewable			Petrol	0.33	0.39	0.41	0.43	0.45	0.47	0.50
			Diesel	1.07	1.16	1.41	1.75	2.26	2.99	4.09
			Kerosene	0.02	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.14	0.14	0.15	0.15	0.16	0.16	0.17
			LPG	0.31	0.32	0.35	0.39	0.44	0.52	0.63
			Coal	0.05	0.05	0.07	0.10	0.13	0.19	0.27
Total				19.59	19.73	19.85	20.47	21.64	23.48	26.26

Figure 8-1 depicts the growth primary solid biomass (fuelwood, agri - residue and animal dung) will remain high in future years as well, under no intervention. Wherein electricity demand would grow at nearly 4.7% per annum, its demand in the total share will still be low. The share of electricity would increase by nearly 1.5 times in 2030 and four-fold in 2050.

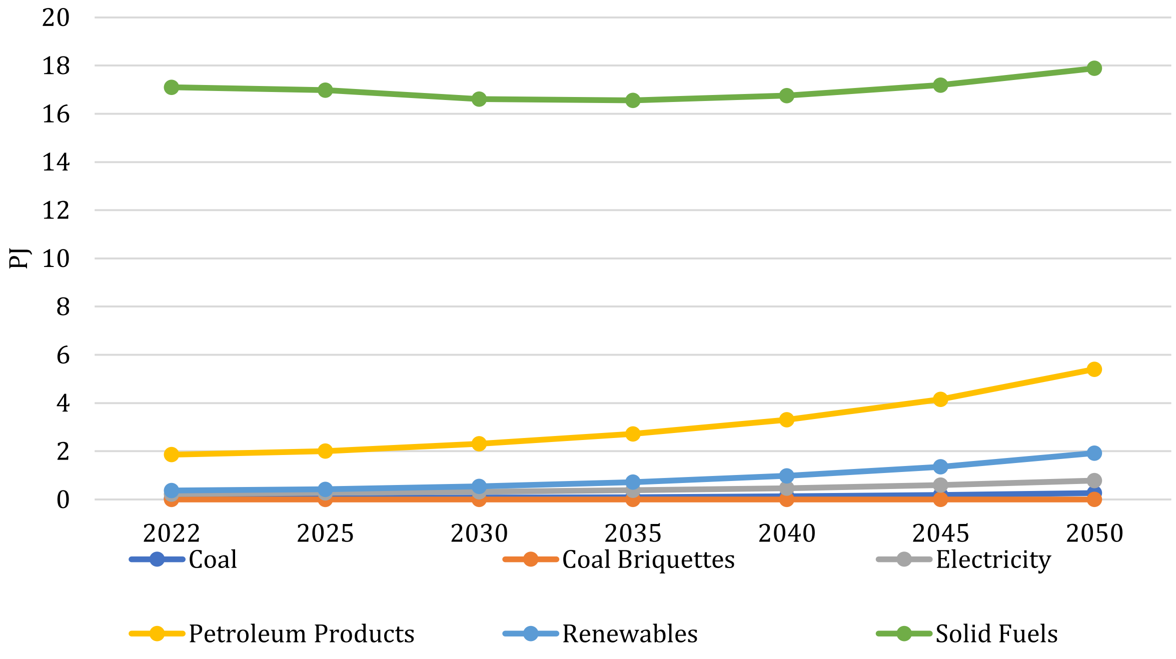


Figure 8-1. Fuel Demand Trend at Low Economic Growth Scenario

Figure 8-2 shows the energy mix in the total fuel demand which suggests demand for solid biomass is expected to decrease to 84% of the total final energy demand in 2030 and 68% in year 2050 respectively, yet this is not significant decrease. Compared to 2022, the demand of petroleum products would grow by to three times in year 2050, reaching share of 21% while the electricity demand share would be only 3% in 2050 respectively. It signals that there will be a strong need for some intervention for promotion of electrification and renewable energy.

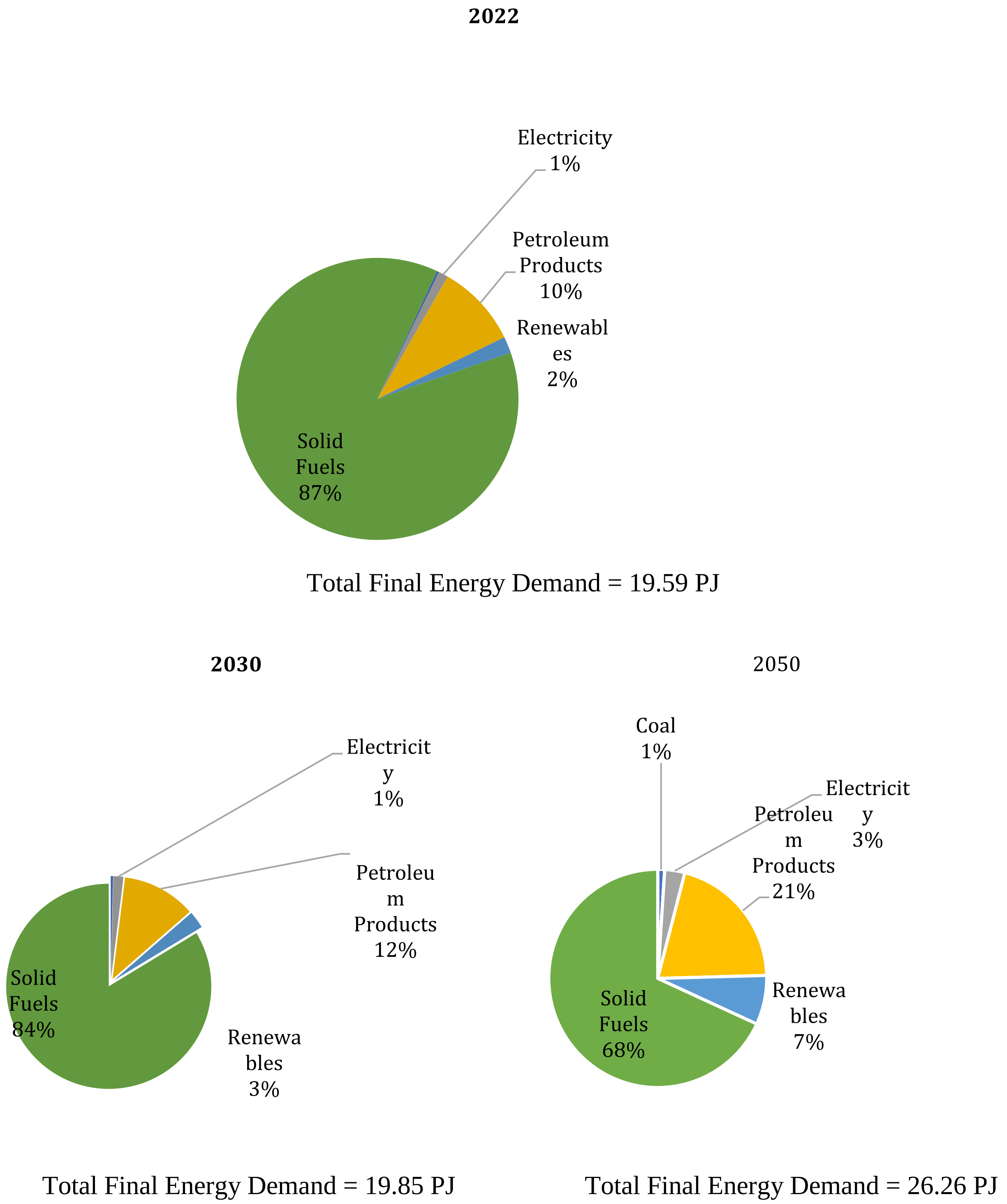


Figure 8-2. Fuel mix at Low Economic Growth Scenario

Table 8-2 shows the sectoral energy demand in this scenario. The share of the residential sector decreases to 61% in 2050 from 86% in 2022. Although there is an increase in energy demand, this is quite low in the case of Karnali, and there is high usage of non-efficient technologies. Meanwhile, the industrial sector’s share of energy demand will increase to 7% in 2050 because of slowly increasing manufacturing sub-sector. Whereas the share of energy demand in the transport sector will grow slightly to 6%. It is therefore crucial to put more focus on improving energy efficiency in the residential sector in Karnali.

Table 8-2: Sectoral demand at Low Economic Growth Scenario (PJ)

	2022	2025	2030	2035	2040	2045	2050
Agriculture	0.25	0.28	0.37	0.50	0.68	0.95	1.36
Commercial	1.10	1.19	1.43	1.78	2.30	3.06	4.18
Construction and Mining	0.21	0.24	0.32	0.43	0.59	0.83	1.18
Industry	0.37	0.39	0.51	0.69	0.95	1.32	1.89
Residential	16.77	16.59	16.12	15.90	15.85	15.91	16.06
Transport	0.89	1.04	1.10	1.17	1.27	1.40	1.58
Total	**19.59**	**19.73**	**19.85**	**20.47**	**21.64**	**23.48**	**26.26**

Sub-sectoral energy demand projections are given in the annex.

Figure 8-3 shows the installed power plant capacity required for the study period with 30% planning reserve on expected peak load. The required peak power plant in 2022 was 17 MW. The future power requirement would be nearly 50 MW in 2030 and 125 MW in 2050 to fulfill the electricity demand of about 221 GWh and 547 GWh in 2030 and 2050 respectively.

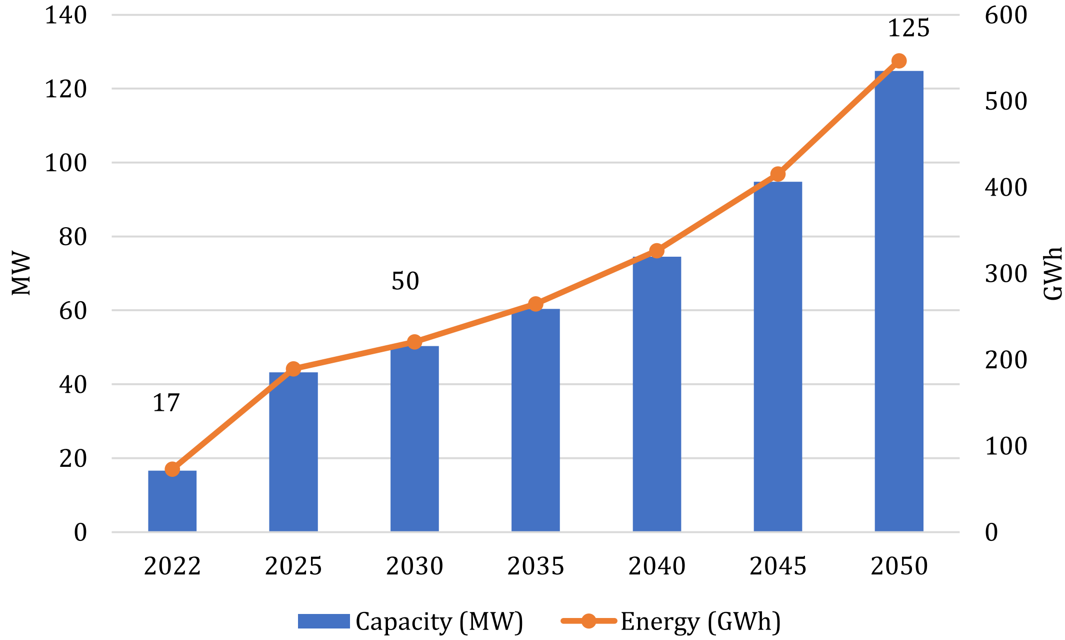


Figure 8-3. Installed Power Plant Capacity Requirement Low Economic Growth Scenario

GHG emissions trend in Low Economic Growth Scenario is as shown in **Figure 8-4** which is low in the province, mainly due to use of solid biomass fuels. GHG emissions would increase from 261 kt in 2022 to 294 kt in 2030 and will reach 541 kt in 2050. The GHG emissions would grow at an average growth rate of 2.6% during 2022-2050. GHG emissions will be double in 2050 from their base year value and it is mainly attributed to demand of fossil fuels in the Karnali Province.

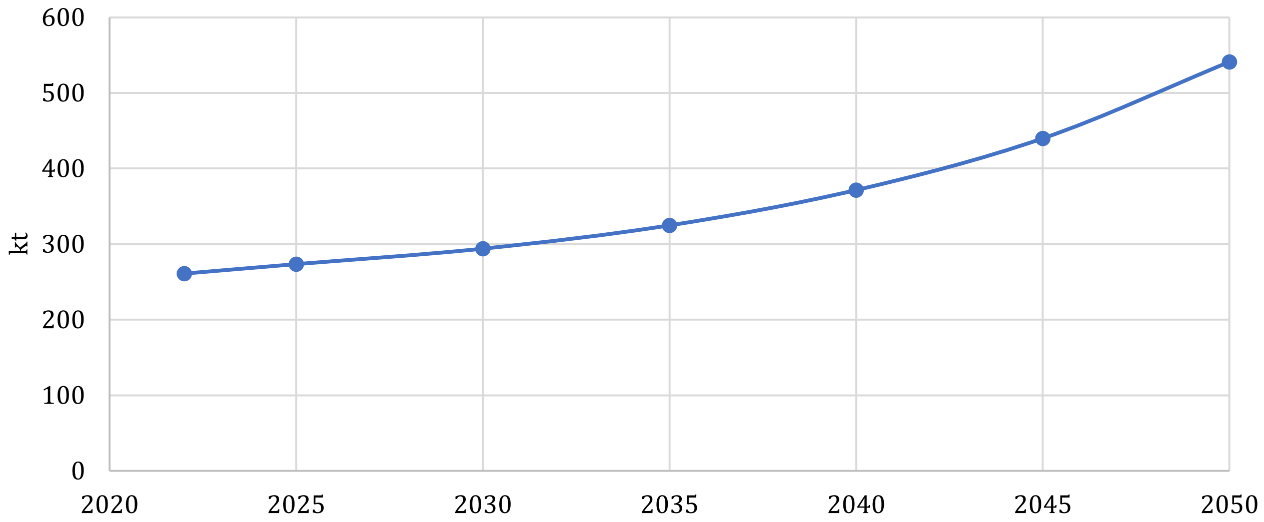


Figure 8-4. GHG emissions at Low Economic Growth Scenario

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

Table 8-3 gives the energy indicators for Low 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 only increase by merely 10% with respect to current demand. Meanwhile, the share of renewables is also expected to increase slightly in years coming by, but in the other hand the net import of fuel in also seen to double in 2050 from 2022, all due to increase in carbon-based energy demand and the conventional demand technologies. Although in being small quantity, the imported carbon-based fuels and their uses are also going to impact per capita GHG emissions reaching almost twice by 2050 from the current baseline values.

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

		2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Final energy demand/capita	GJ/capita	11.61	11.44	11.12	11.07	11.30	11.84	12.79
Final electricity demand	kWh/capita	96	110	133	164	209	272	365
Final energy demand	GJ/million NRS	114	101	77	59	45	35	28
Final Electricity Demand	kWh/million NRS	944	972	919	874	838	808	786
Total Electricity Used/household	kWh/HH	109	109	109	109	109	109	109
Share of carbon energy in primary supply	per cent	9.75 %	10.45 %	12.00 %	13.75 %	15.90 %	18.49 %	21.58 %
Share of renewable energy in final total energy demand	per cent	3.00 %	3.48%	4.31%	5.36%	6.67%	8.30%	10.29 %
The ratio of net import to total primary energy supply	per cent	9.74 %	10.44 %	12.00 %	13.75 %	15.90 %	18.48 %	21.57 %
GHG emission	GHG in Kg/capita	154	159	165	176	194	222	264

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

Table 8-4 below shows the total energy demand for the High Economic Growth case of various fuel types from base year to year 2050. The total energy demand in Karnali Province is expected to grow from the current level of 19 PJ in 2022 to 20 PJ in 2030 and 33 PJ in the year 2050 which accounts for only 1.5 folds of increase. The average annual growth rate of energy demand is 1.9% for the HIH case which is higher than the LOW scenario case because of expected higher economic activities in this scenario, demanding more energy.

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*	17.10	17.00	16.67	16.72	17.12	17.97	19.51
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.37	0.42	0.57	0.82	1.23	1.93	3.22
			Grid Electricity	0.22	0.27	0.33	0.41	0.55	0.78	1.20
Non-renewable			Petrol	0.33	0.39	0.41	0.43	0.45	0.49	0.54
			Diesel	1.07	1.16	1.43	1.85	2.54	3.74	5.90
			Kerosene	0.02	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.14	0.15	0.21	0.31	0.46	0.74	1.24
			LPG	0.31	0.32	0.35	0.41	0.49	0.63	0.87
			Coal	0.05	0.06	0.08	0.11	0.17	0.27	0.45
Total				19.59	19.77	20.06	21.05	23.02	26.56	32.95

The share of primary solid biomass (fuelwood, agri- residue and animal dung) is high throughout the period and will be growing at an annual rate of 0.5%. Petroleum and coal demand are expected to grow at the rate of 5.6% and 8.3% respectively, whereas electricity demand would grow at 6.3% per annum (**Figure 8-**5). Thus, with low penetration of electric technology and other efficient technologies, the growth in clean energy is low. Thus, in HIH scenario too, the demand for petroleum products will be higher than the demand for solid biomass, but at a higher rate than in LOW scenario.

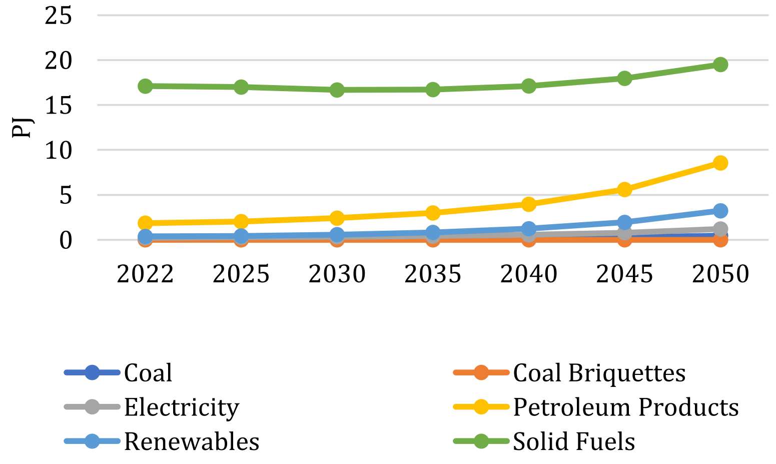
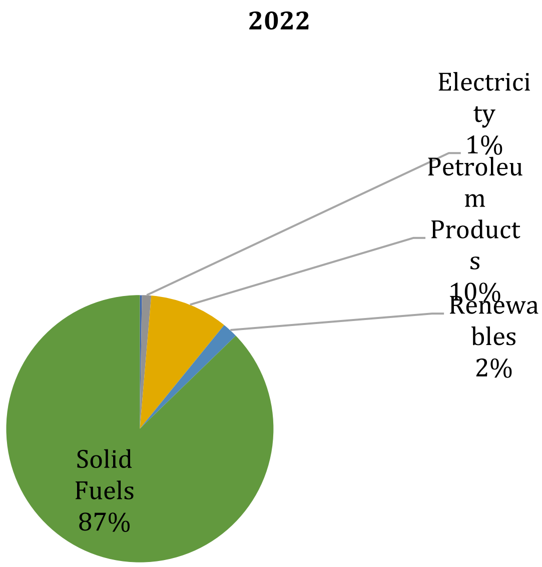
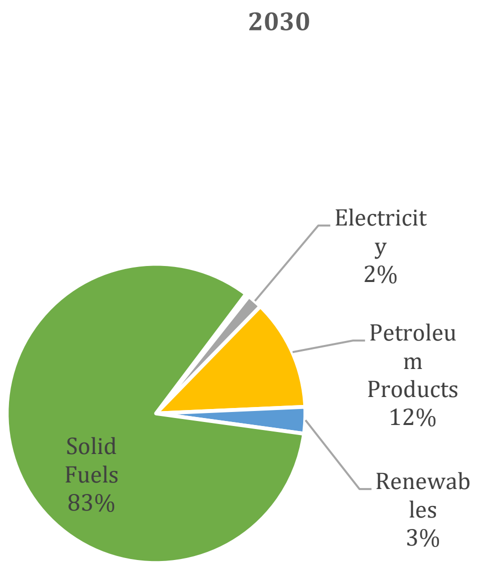


Figure 8-5. Fuel Demand Trend at High Economic Growth Scenario

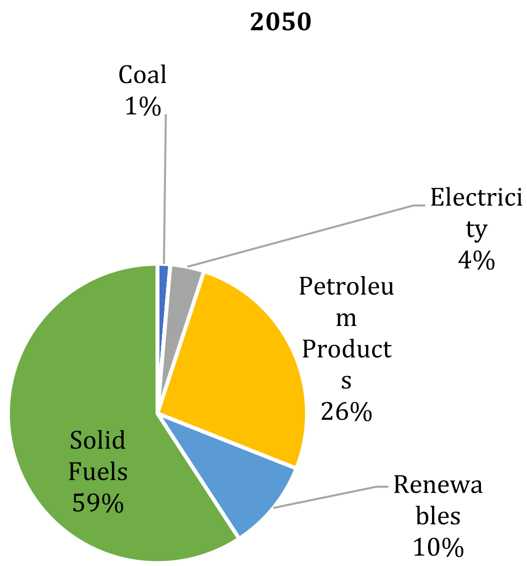
Figure 8-6 shows the energy mix in the total fuel demand for 2022, 2030 and 2050 years. The demand of solid biomass is expected to decrease to 83% in 2030 and 59% in the year 2050 respectively. Compared to 2022, the share in demand of petroleum products would grow to 26% in 2050. The electricity demand share would be 4% in 2050 and modern renewables will achieve a share of 10% in 2050 in the HIH scenario.



(a) Total Final Energy Demand = 19.6 PJ



(b) Total Final Energy Demand = 20 PJ



(c) Total Final Energy Demand = 33 PJ

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

Table 8-5 shows the sectoral energy demand in this scenario. The share of the residential sector decreases to 49% in 2050 from 86% in 2022. Meanwhile, the industrial sector's share of energy demand will increase to 3% in 2030 and 10% in 2050. Whereas the share of energy demand in the commercial sector will increase to 22% in 2050 from 6% in 2022. There will be a 7% share of energy demand in the transport sector in 2050 up from 5% in 2022. Thus, in Karnali Province, the energy demand pattern also suggests there will be low economic activities and most of the energy will be consumed in non-productive activities.

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

	2022	2025	2030	2035	2040	2045	2050
Agriculture	0.25	0.28	0.39	0.57	0.86	1.38	2.31
Commercial	1.10	1.22	1.53	2.05	2.92	4.41	7.09
Construction and Mining	0.21	0.25	0.34	0.50	0.75	1.20	2.01
Industry	0.37	0.39	0.55	0.79	1.20	1.91	3.20
Residential	16.77	16.59	16.12	15.90	15.85	15.91	16.06
Transport	0.89	1.04	1.13	1.25	1.44	1.75	2.29
Total	**19.59**	**19.77**	**20.06**	**21.05**	**23.02**	**26.56**	**32.95**

Sub-sectoral energy demand projections are given in the annex.

Figure 8-7 shows the installed power plant capacity required for the study period. The future installed power plant requirement would be 52 MW in 2030 and 160 MW in 2050 from current demand of 17 MW. The electricity demand will grow at the rate of 8.4% with improving economic activities and electrification happening.

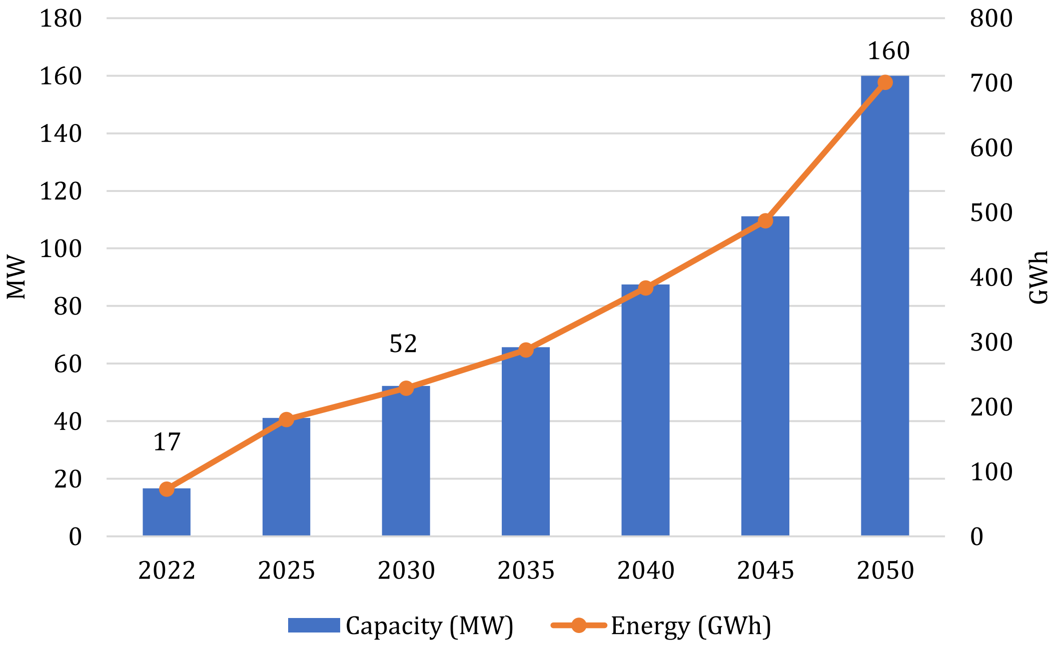


Figure 8-7. Installed Power Plant Capacity Requirement High Economic Growth Scenario

GHG emissions trend in High Economic Growth Scenario is as shown in **Figure 8-8.** GHG emissions would increase to 301 kt in 2030 and can reach 792 kt in 2050. The GHG emissions would grow at an average growth rate of 4% during 2022-2050, reaching nearly 3 times the current GHG emissions in 2050. Although the increase in emission is lower than other provinces, the increasing demand for fossil fuels in the Karnali Province will contribute to growth in GHG emissions.

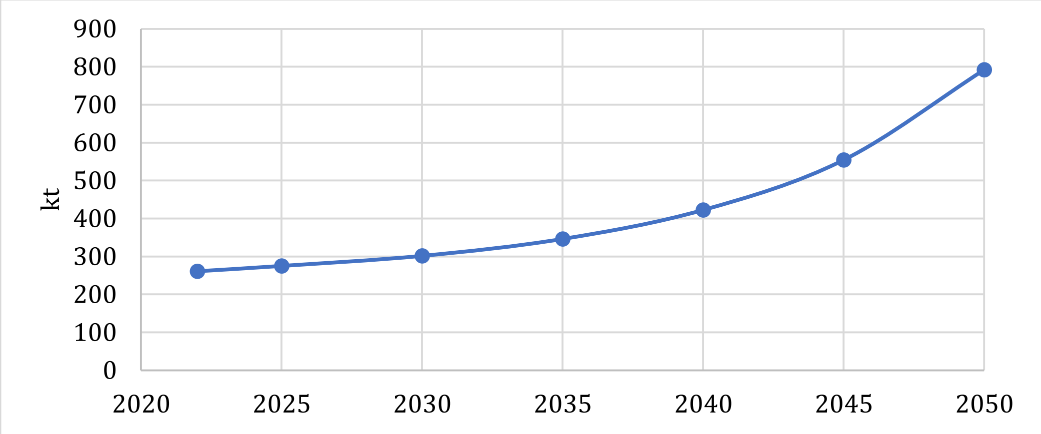


Figure 8-8. GHG Emissions at High Economic Growth Scenario

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

Table 8-6 gives the energy indicators for High 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 be nearly 1.5 times in 2050 with respect to current demand. Meanwhile, the share of renewables is also expected to increase by more than 4 folds, but in the other hand the net import of fuel in also seen to reach 27% in 2050 from 10% 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 more than two times by 2050 from the current baseline values.

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

		2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Final energy demand/capita	GJ/capita	11.61	11.47	11.24	11.39	12.03	13.40	16.05
Final electricity demand	kWh/capita	96	112	140	185	257	381	599
Final energy demand	GJ/million NRS	114	99	73	53	38	28	20
Final Electricity Demand	kWh/million NRS	944	967	906	855	814	783	761
Total Electricity Used/household	kWh/HH	109	109	109	109	109	109	109
Share of carbon energy in primary supply	per cent	9.76 %	10.54 %	12.41 %	14.75 %	17.92 %	22.12 %	27.36 %
Share of renewable energy in final total energy demand	per cent	3.00 %	3.52%	4.50%	5.86%	7.72%	10.25 %	13.45 %
The ratio of net import to total primary energy supply	per cent	9.74 %	10.52 %	12.38 %	14.72 %	17.90 %	22.09 %	27.34 %
GHG emission	GHG in Kg/capita	154	159	169	187	221	280	386

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

Table 8-7 below shows the total energy demand for the reference growth case of various fuel types from base year to year 2050. The total energy demand in Karnali Province is expected to grow from the current level of 19 PJ in 2022 to 20 PJ in 2030 and 28 PJ in the year 2050. The average annual growth rate of energy demand is 1.3% for the reference case where the highest growing fuels are solar and coal. It is obvious that, the region being geographically challenging, the increase in of grid solar is expected.

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***	17.10	16.98	16.62	16.59	16.85	17.43	18.45
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	**Biogas**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		**Solar PV**	0.37	0.41	0.54	0.74	1.04	1.53	2.37
			Grid Electricity	0.22	0.27	0.32	0.39	0.49	0.65	0.93
Non-renewable			**Petrol**	0.33	0.39	0.41	0.43	0.45	0.48	0.52
			Diesel	1.07	1.16	1.42	1.79	2.39	3.34	4.95
			Kerosene	0.02	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.14	0.14	0.15	0.15	0.16	0.16	0.17
			LPG	0.31	0.32	0.35	0.39	0.46	0.55	0.72
			Coal	0.05	0.05	0.07	0.10	0.14	0.21	0.33
Total				19.59	19.74	19.88	20.58	21.98	24.37	28.43

The share of primary solid biomass (fuelwood, agri - residue and animal dung) will remain high throughout the period which is expected to grow at the rate of 1.3% whereas electricity demand would grow at 5.3% per annum (**Figure 8-9)**. The share of electricity will remain below 4% in absence of interventions.

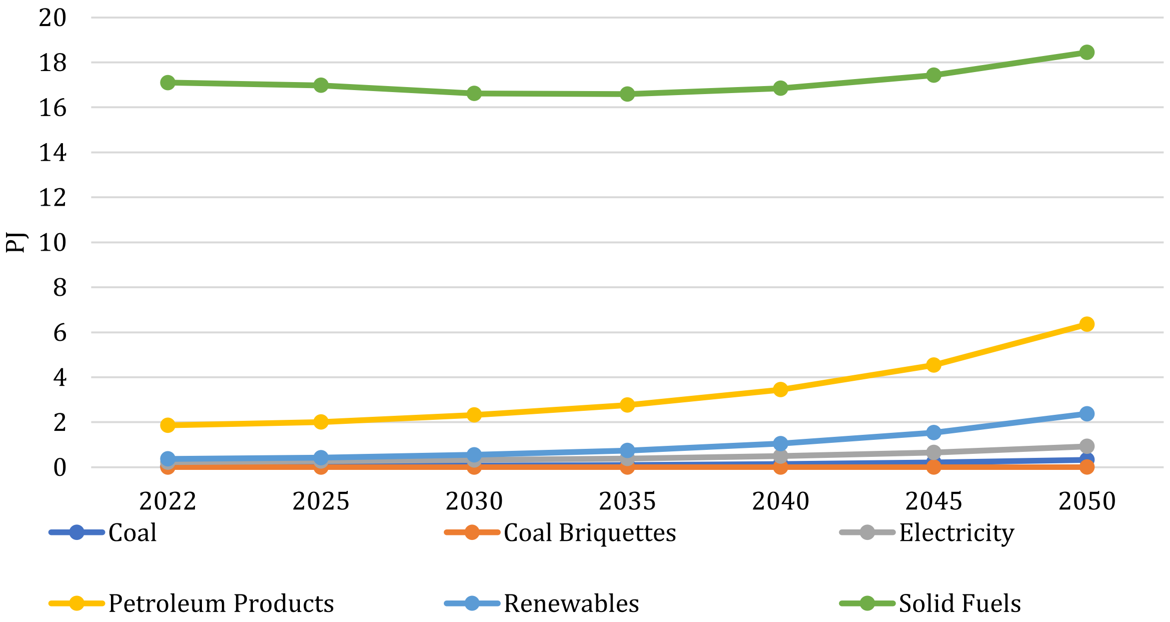
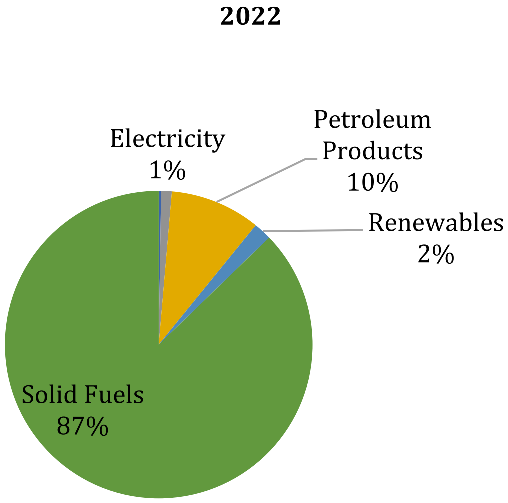
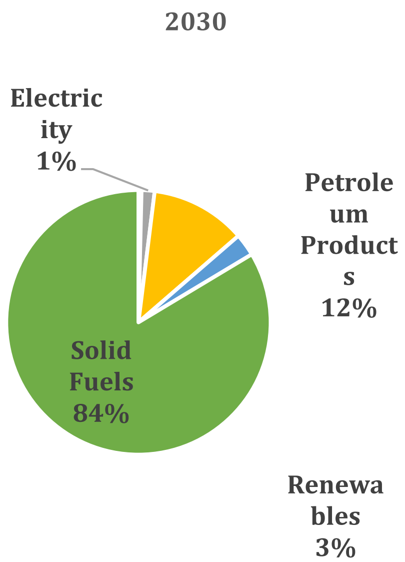


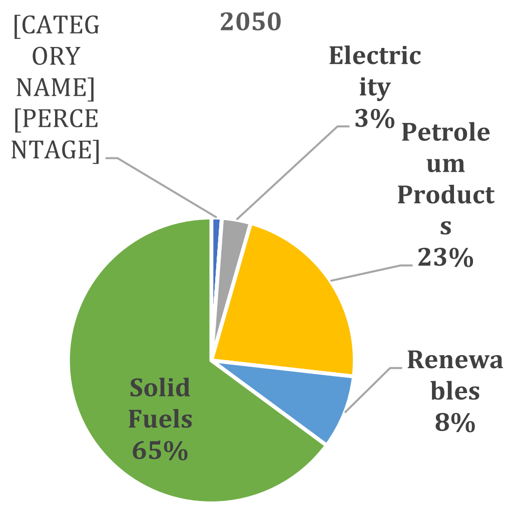
Figure 8-9. Fuel Demand Trend at Reference Economic Growth Scenario

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 84% in 2030 and 65% in the year 2050 respectively. Compared to 2022, the demand of petroleum products would reach 23% in 2050. The electricity demand share would be little over 1% in 2030 and 3% in 2050 respectively. Modern renewables will have a share of 8% of the total energy demand in 2050.



Total Final Energy Demand = 19.6 PJ





(b) Total Final Energy Demand = 20 PJ (c) Total Final Energy Demand = 28 PJ

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

Table 8-8 shows sectoral energy demand in this scenario. The share of the residential sector decreases to 57% in 2050 from 86% in 2022. Meanwhile, the industrial sector's share of energy demand will increase to 3% in 2030 and 8% in 2050. Whereas the share of Energy demands in the commercial sector will increase to 18% from its base year value of 6%. The share of energy demand in the transport sector will also increase to 6% in 2050 from 5% in 2022.

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

	2022	2025	2030	2035	2040	2045	2050
Agriculture	0.25	0.28	0.37	0.51	0.73	1.09	1.69
Commercial	1.10	1.20	1.45	1.84	2.47	3.48	5.18
Construction and Mining	0.21	0.24	0.32	0.45	0.63	0.94	1.47
Industry	0.37	0.39	0.52	0.71	1.01	1.51	2.34
Residential	16.77	16.59	16.12	15.90	15.85	15.91	16.06
Transport	0.89	1.04	1.10	1.17	1.28	1.45	1.69
Total	**19.59**	**19.74**	**19.88**	**20.58**	**21.98**	**24.37**	**28.43**

Sub-sectoral energy demand projections are given in the annex.

As indicated by **Figure 8-11,** without active efforts to encourage clean and renewable energy, Karnali Province is poised to continue its heavy reliance on biomass energy sources. Additionally, there is a growing dependence on imported petroleum, resulting in a significant increase in the demand for fossil fuels by 2050. The sustainability of such a substantial demand for biomass energy extracted from the province's forests is a matter of significant concern. Moreover, valid apprehensions arise regarding the economic feasibility of Karnali Province in sustaining the prolonged importation of such substantial quantities of fossil fuels.

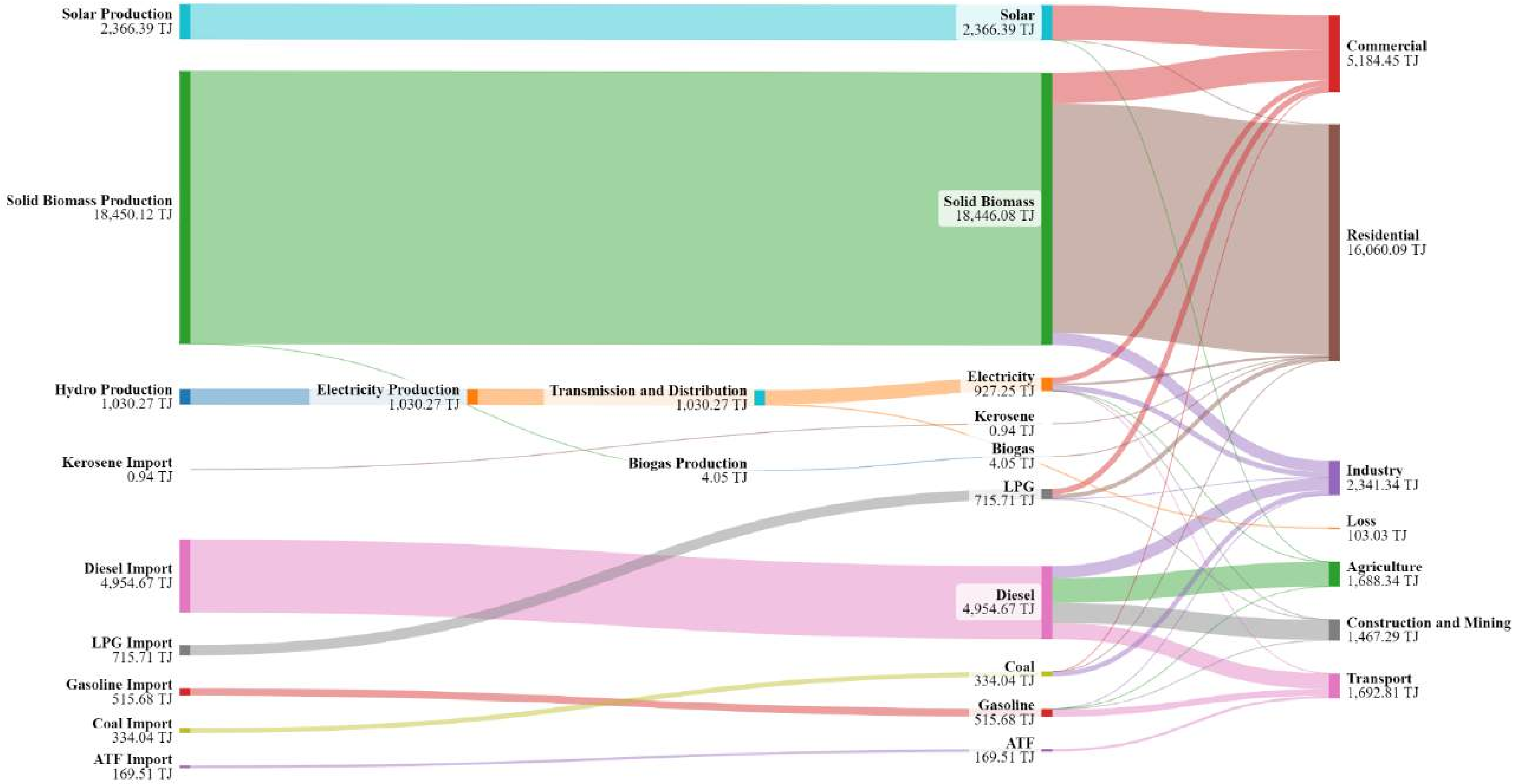


Figure 8-11. Sankey Diagram for Flow of Energy in Karnali Province for the Reference Economic Growth Scenario in 2050

Figure 8-12 shows the installed power plant capacity required for the study period. The future installed power plant capacity required for Karnali Province will grow to nearly 10 times the current capacity due to increasing electricity demand that grows at 8.1%. Therefore, to fulfill the demand, the total power plant capacity required in the year 2030 will be about 51 MW while it will be about 148 MW by 2050.

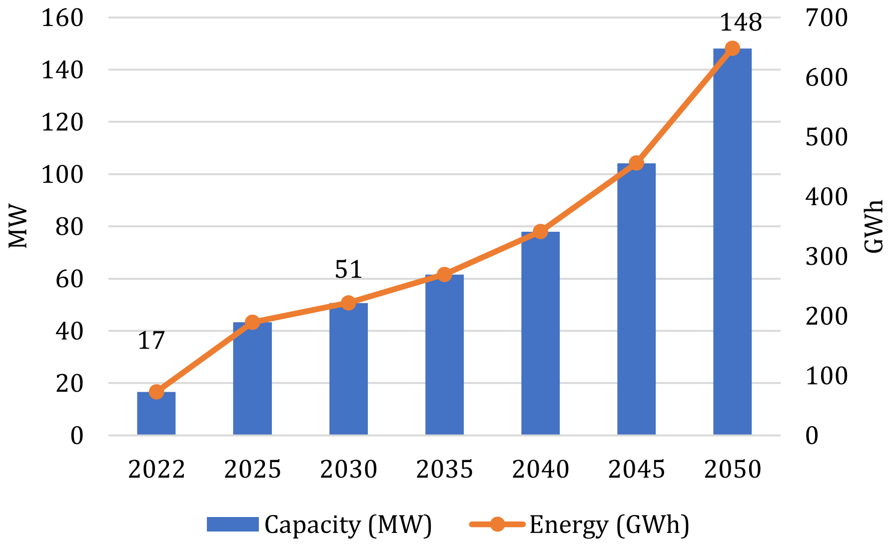


Figure 8-12. Installed Power Plant Capacity Requirement Reference Economic Growth Scenario

GHG emissions trend in Reference Economic Growth Scenario is as shown in **Figure 8-13.** GHG emissions in the reference scenario will be growing at 3.1% per annum. GHG emissions increase from 261 kt in 2022 to 295 kt in 2030 and consequently about 619 kt in 2050, i.e., the emissions would nearly triple in the three decades.

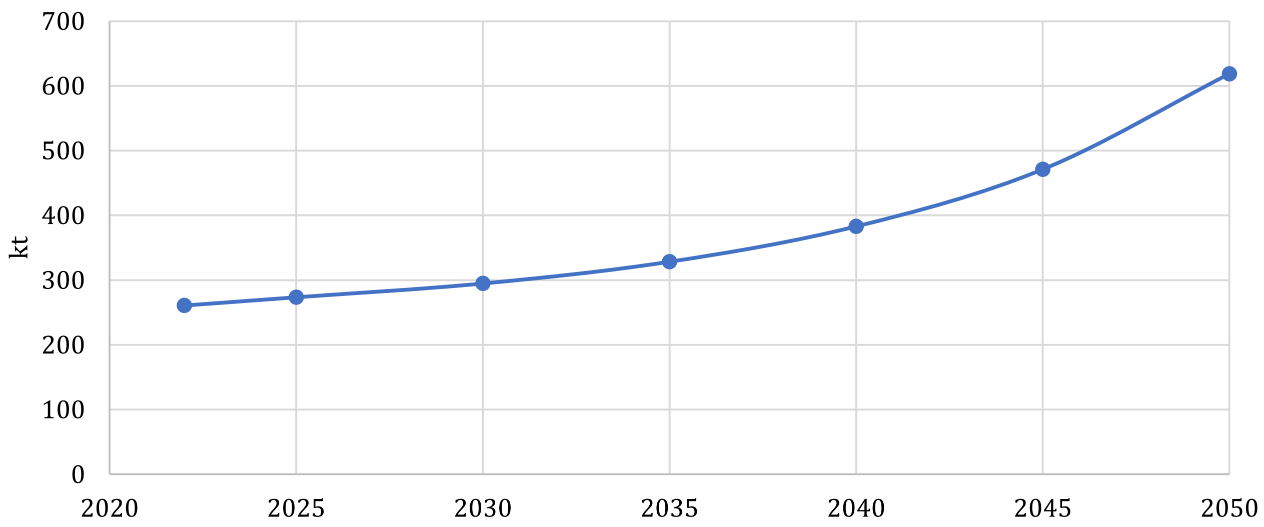


Figure 8-13. GHG Emissions at Reference Economic Growth Scenario

- **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. In the case of Karnali Province where energy consumption is already lower, the total energy intensity per capita would increase only by 20% times in 2050 with respect to 2022. Meanwhile the per capital electricity demand will increase by nearly 5 times. Although the increase in electricity consumption per capita is very high, the total amount is not as high comparatively to other provinces. On the other hand, the share of renewable energy in the energy mix will increase by three times and the petroleum products will be doubled in 2050. The result of it is the emission will also increase by two times by 2050 with respect to 2022 and reach 300 kg per capita from the base your value of 154 per capita.

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

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	11.61	11.45	11.13	11.13	11.48	12.30	13.85
Final electricity demand	kWh/capita	96	110	134	169	222	306	446
Final energy demand	GJ/million NRS	114	101	76	57	43	32	24
Final Electricity Demand	kWh/million NRS	944	971	916	870	830	798	774
Total Electricity Used/household	kWh/HH	109	109	109	109	109	109	109
Share of carbon-based energy in primary supply	per cent	9.76 %	10.48 %	12.07 %	13.94 %	16.37 %	19.52 %	23.54 %
Share of renewable energy in final total energy demand	per cent	3.00 %	3.49%	4.35%	5.47%	6.97%	8.98%	11.60 %
The ratio of net import to total primary energy supply	per cent	9.74 %	10.46 %	12.05 %	13.91 %	16.34 %	19.50 %	23.52 %
GHG emissions	GHG in Kg/capita	154	159	165	178	200	238	301

8.1.4 Sustainable Energy Development (SED) Scenario

In this scenario, all combined policy measures are considered with various technology Interventions. The major focus is on electrification by renewable energy and energy efficiency in various demand technologies. The assumptions are in line with the various published reports and documents of Nepal Governmental agencies, IEA, IRENA, Paris Agreement, 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
- 100% electrification in farm machineries by 2050

Commercial sector

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

Transportation

- Intercity transport
    - 20% electric car by 2050
    - 50% electric bus by 2050
    - 10% electric motorcycle by 2050
    - 10% fuel cell electric car by 2050
    - 10% fuel cell electric bus by 2050
- Intercity transport
    - 40% electric bus by 2050
    - 20% electric car by 2050
    - 30% electric train by 2050
    - 10% airplane
- Freight
    - 40% electric train by 2050
    - 60% electric vehicles by 2050

Industry:

- Process heat and thermal use: 80% alternative especially fuelwood; 5% electricity; 15% coal.
- Boiler: 30% electricity; rest renewable solid fuels
- Motive power: 100% Electric.
- Other: 50% Electric; 20% coal; solid biomass

Residential sector:

- Rural cooking and water heating: 30% electric, 40% ICS and 30% LPG by 2050
- Rural others: 50% electrification, 30% LPG, 20% fuelwood by 2050
- Rural: 100% electrification in rest
- Urban cooking and water heating: 50% electrification, 30% LPG by 2050
- Urban others: 50% electrification, 30% 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.** In the case of SED scenario, the total energy demand in Karnali Province is expected to be lower than the base value by 2050. The decrease in total energy consumption is due to the intervention of efficient technologies. Biomass consumption will also decrease to nearly halve by 2050 compared to 2022. Meanwhile electricity consumption will increase by 21 times. On the other hand, the consumption of petroleum products will also increase but the total consumption will not be as much high in respect to other provinces in Nepal due to limited economic activities in the region.

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

SEDS	2022	2025	2030	2035	2040	2045	2050

Renewables	**Conventional renewable**	**Traditional biomass**	**PSF***	17.10	12.28	6.97	6.26	5.52	4.78	4.04
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	**Biogas**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		**Solar PV**	0.37	0.41	0.54	0.73	1.03	1.53	2.36
			Grid Electricity	0.22	0.49	0.94	1.50	2.20	3.12	4.50
Non-renewable			**Petrol**	0.33	0.27	0.25	0.22	0.19	0.17	0.15
			Diesel	1.07	1.00	1.12	1.27	1.57	2.12	3.02
			Kerosene	0.02	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.14	0.14	0.15	0.15	0.16	0.16	0.17
			LPG	0.31	0.29	0.26	0.23	0.20	0.16	0.12
			Coal	0.05	0.05	0.06	0.07	0.09	0.11	0.13
Total				**19.59**	**14.94**	**10.28**	**10.43**	**10.96**	**12.15**	**14.50**

In this scenario the total final energy demand will decrease at the rate of 1.1% from 2022 to 2050, mainly due to decrease in demand of solid biomass whose demand decrease by 5% per annum. On the other hand, the share of renewables and petroleum would increase at the rate of 7% and 2.2% respectively in 2050. The overall energy demand will be dominated by solid biomass but at very end of the period, electricity would surpass the solid biomass demand. The energy demand trends are highlighted in **Figure 8-14.**

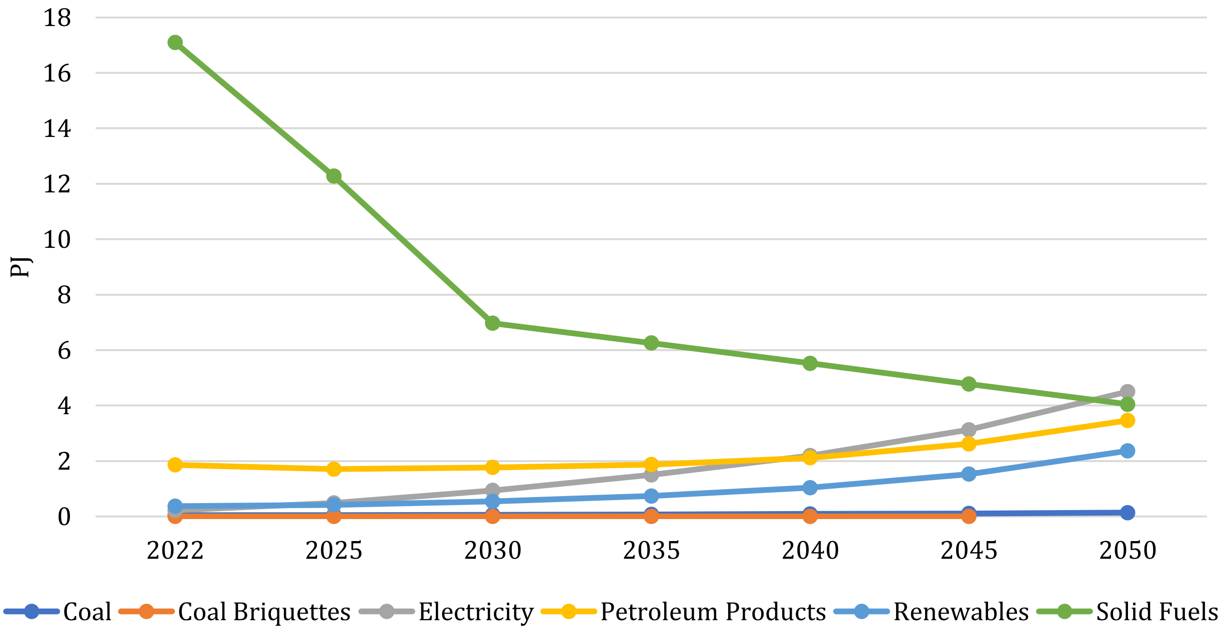
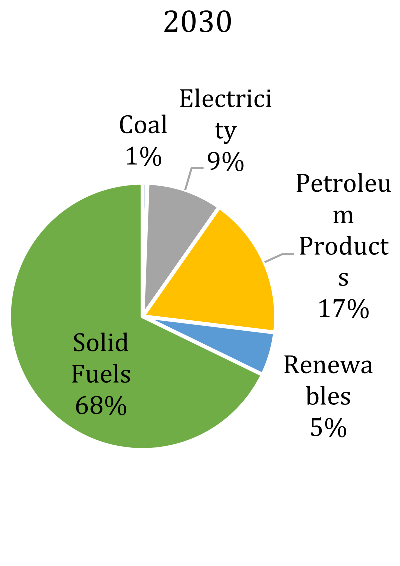
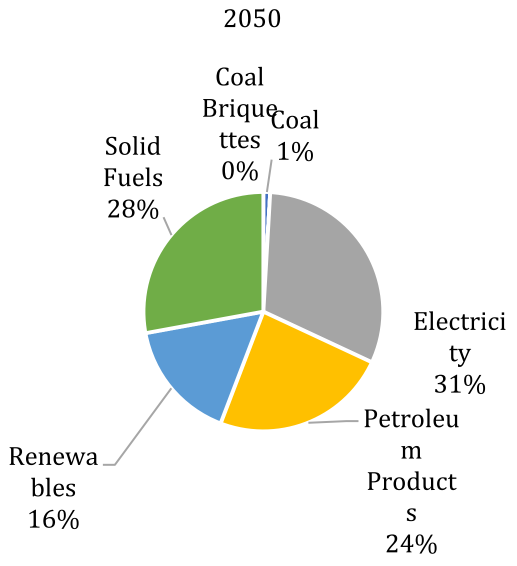


Figure 8-14. Fuel demand trend at Sustainable Energy Development Scenario (SEDS)

The **Figure 8-**15 below show the energy mix in the total energy demands for 2030 and 2050 years. With intervention of efficient technologies for wood using technologies, the share of biomass consumption would decrease from 87% in 2022 to 68% in 2030 and 28% in 2050. The other forms of energy would on the other hand increase – petroleum to 24%, electricity to 31% and renewables to 16%. Thus, in 2050, biomass demand will be surpassed by electricity, being the dominant fuel in Karnali Province.



(a) Total Final Energy Demand = 10 PJ



(b) Total Final Energy Demand = 15 PJ

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

Table 8-11 shows the sectoral energy demand in this scenario. In the case of sectoral energy consumption, there will be less growth in residential sector due to energy efficient technology interventions. The shares of energy demand in agricultural, commercial and industry will attain 8%, 28% and 10% of the total energy demand in 2050 respectively. The energy demand in residential sector would decrease from 86% in 2022 to 32% in 2050. The energy demand for transportation would increase from 5% in 2022 to 7% in 2050.

Table 8-11: Sectoral demand at Sustainable Energy Development Scenario (SEDS) (PJ)

	2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Agriculture	0.25	0.26	0.31	0.38	0.51	0.78	1.22
Commercial	1.10	1.04	1.08	1.42	1.93	2.74	4.06
Construction and Mining	0.21	0.24	0.32	0.45	0.63	0.94	1.47
Industry	0.37	0.38	0.49	0.64	0.88	1.25	1.86
Residential	16.77	12.18	7.23	6.67	6.05	5.38	4.66
Transport	0.89	0.83	0.85	0.88	0.95	1.06	1.24
Total	**19.59**	**14.94**	**10.28**	**10.43**	**10.96**	**12.15**	**14.50**

As seen in **Figure 8-16,** the Sankey diagram reveals a notable transition from a predominant reliance on solid biomass for meeting energy requirements to a scenario where electricity assumes a more prominent role, as per the SED Scenario projections for 2050. This evolution in Nepal's energy landscape suggests a substantial increase in electricity generation from clean and renewable sources in the Karnali Province. This shift not only bolsters energy security but also fosters sustainability in the region by reducing dependence on non-renewable resources.

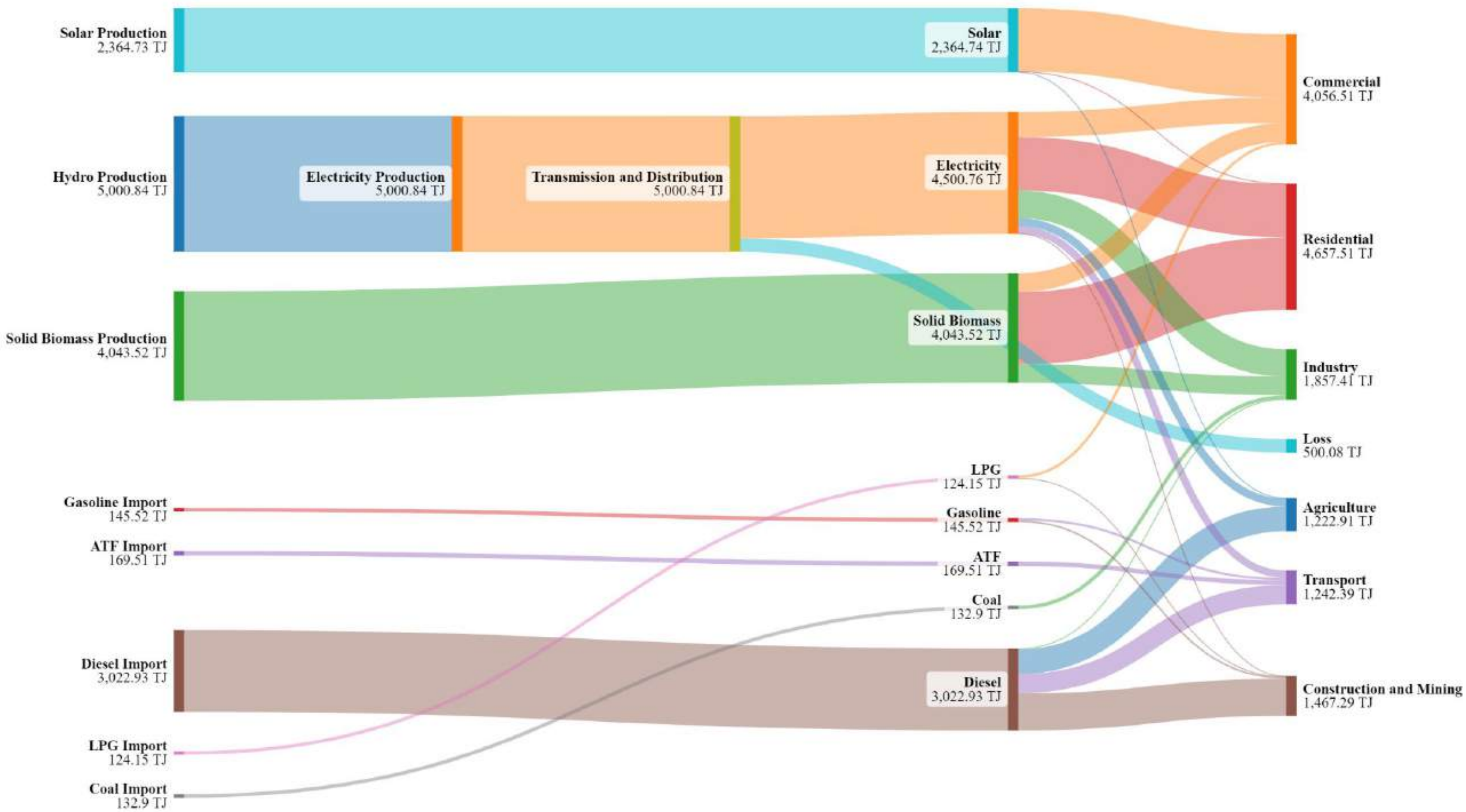


Figure 8-16. Sankey Diagram for Flow of Energy in Karnali Province for the Sustainable Energy Development Scenario in 2050

The installed power plant capacity requirement in this scenario is as shown in **Figure 8-17.** To cater for the increasing electricity demand which reaches 640 GWh in 2030 and 2,653 GWh in 2050. The installed power plant capacity required for Karnali Province will be 146 MW by 2030 and 606 MW by 2050, including the reserve margin of 30%.

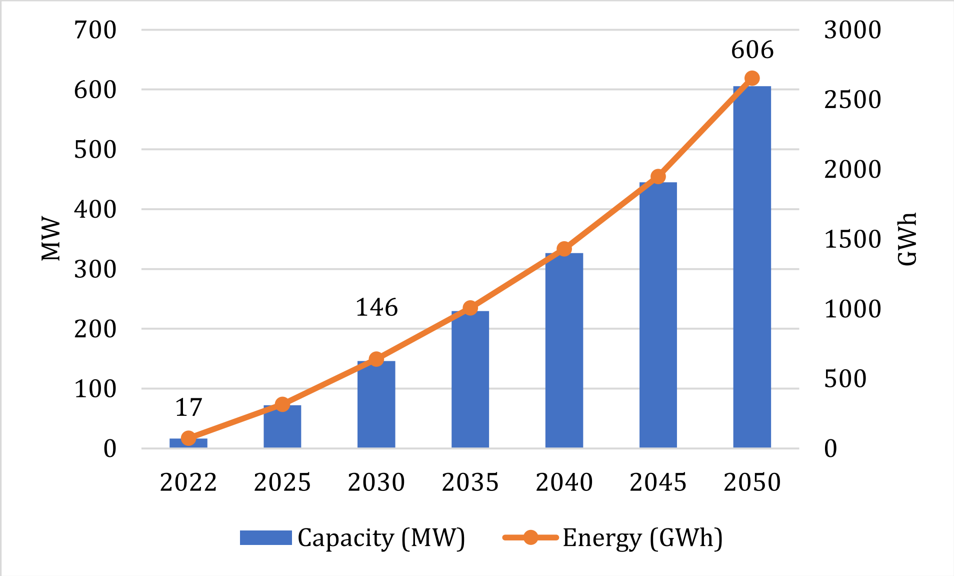


Figure 8-17. Power Plant Capacity in Sustainable Energy Development Scenario (SEDS)

GHG emissions trend in Sustainable Energy Development Scenario (SEDS) is shown in **Figure 8-**18. The total GHG emissions in 2022 account for 261 kt while in SEDS scenario, this would decrease to 183 kt in 2030 and then increase to 292 kt in 2050. 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 which Nepal has pledged targets 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).

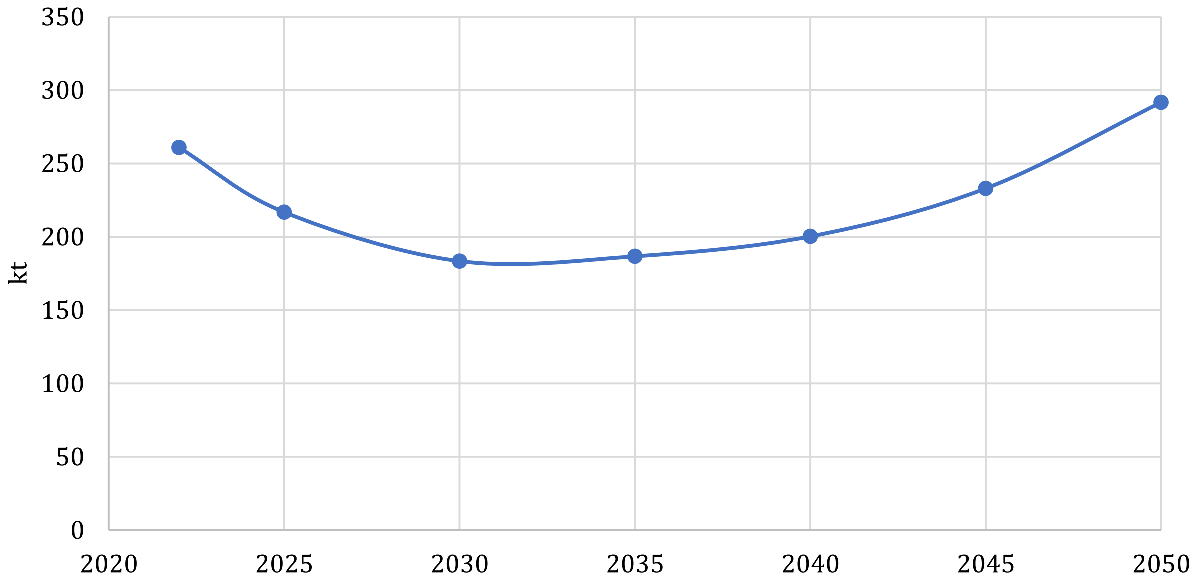


Figure 8-18. GHG Emissions at Sustainable Energy Development Scenario (SEDS)

- **Energy Indicators in the Sustainable Energy Development Scenario (SEDS)**

Table 8-12 shows the energy indicator for policy scenario ie SEDS which clearly presents the impacts of strategic interventions in energy sector. In this scenario, due to the interventions of efficiency improvement strategies, the total per capita final energy demand would decrease at the rate of nearly negative 1.8% and reach almost as half as reference scenario in 2050. The electricity demand per capita would be double the reference scenario in 2050 and with respect to 2022, it's almost 10 times. On the other hand, the renewable energy share would increase to nearly 47% from the 3% in the base year, while the share of the net fuel import to total primary energy in supply would double in 2050. The result of decrease in petroleum products would help in reduction in GHG emissions in earlier years and would help to limit the GHG emissions within 140 kg per capita in 2050, which is less than half than that in reference 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	11.61	8.66	5.76	5.64	5.72	6.13	7.07
Final electricity demand	kWh/capita	96	145	230	335	469	652	929
Final energy demand	GJ/million NRS	114	76	39	29	21	16	12
Final Electricity Demand	kWh/million NRS	944	1,275	1,576	1,726	1,754	1,699	1,613
Total Electricity Used/household	kWh/HH	109	231	436	640	845	1049	1253
Share of non-carbon energy in primary supply	per cent	9.76%	11.78%	17.82%	18.67%	20.14%	22.43%	24.79%
Share of renewable energy in final total energy demand	per cent	3.00%	6.04%	14.41%	21.38%	29.49%	38.28%	47.34%
The ratio of net import to total primary energy supply	per cent	9.74%	11.76%	17.79%	18.65%	20.12%	22.42%	24.79%
GHG emissions	GHG in Kg/capita	154	126	103	101	105	118	142

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. In the reference scenario the total energy demand would only grow by 1.3% whereas in SEDS scenario, growth rate goes to the negative at negative 1.1% and the result is that the total energy demand in future year will decrease to 10 PJ in year 2030 and will increase slightly to15 PJ by 2050. Due to the improvement in energy efficiency, there will be a reduction in total energy demand as seen from the graph. There will be about 48% reduction in total final energy demand in 2030 with respect to reference scenarios whereas in 2050 there, it will be reduced by 49%.

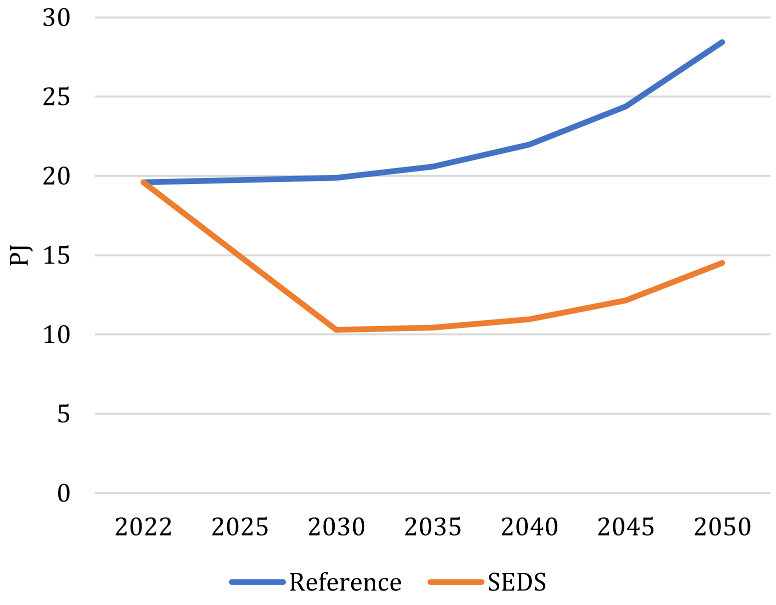


Figure 8-19. Total Final Energy Demand in Karnali Province

Per capita energy intensity will also decrease in the same way as seen in **Figure 8-**20. Since most of the energy is from the residential sector it will take a similar pattern. The energy intensity thus from 12 GJ per capita in 2022 will reduce to 7 GJ per capita which is nearly half with respect to the reference scenario.

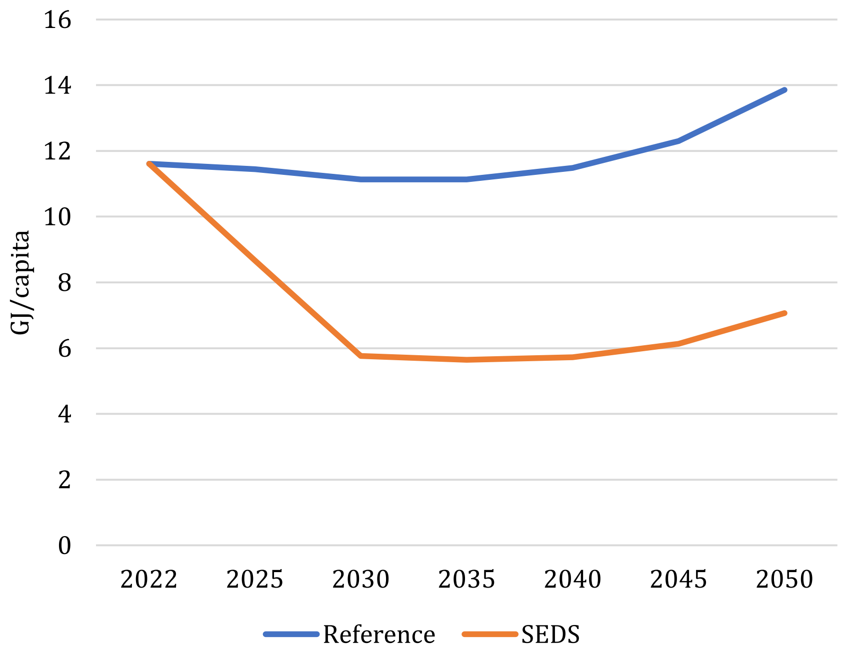


Figure 8-20. Final Energy Demand Per Capita in Karnali Province

Figure 8-21 depicts the electricity demand in compared scenarios which shows that in the SEDS, electricity demand will grow at higher rate of 8.6% per annum, reaching 930 kWh per capita overall due to electrification in almost all possible areas. Meanwhile, the household electricity demand reaches only 1,253 kWh/HH 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.

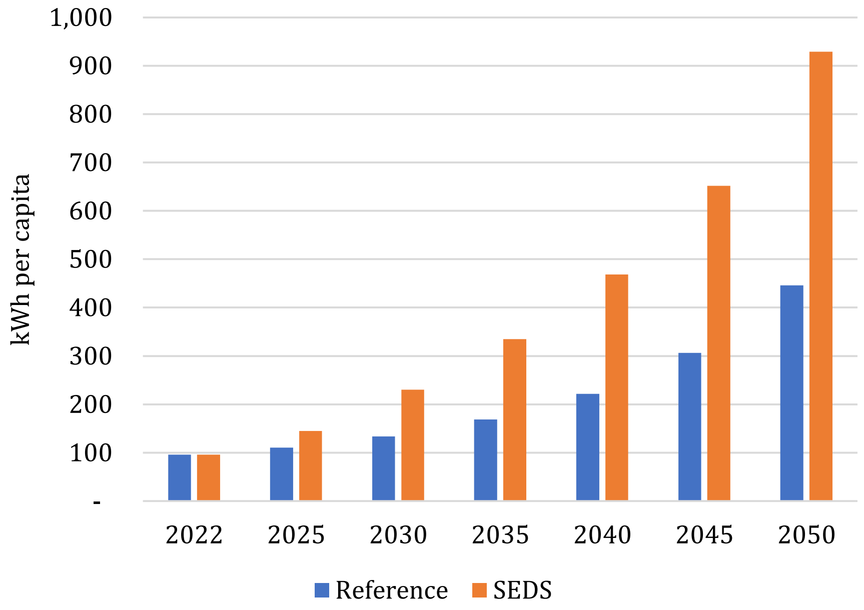


Figure 8-21. Electricity Demand Per Capita in Karnali Province

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 3% in 2022 to 47% in 2050, provided that enough hydropower and power from solar PV are developed provincially and nationally. The share of modern renewables will seem to be lower due to the high share of biomass in the total energy demand.

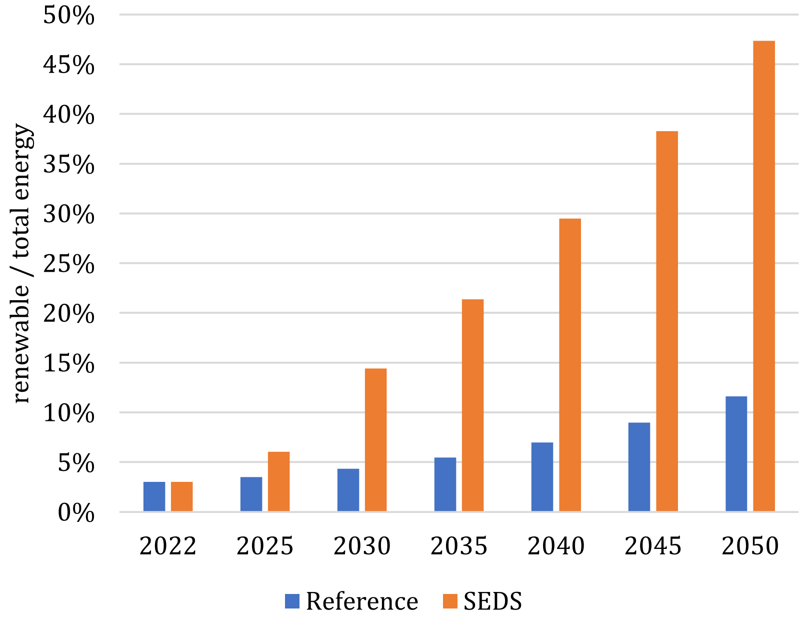


Figure 8-22. Renewable Energy to Total Energy Demand Ratio in Karnali Province

The effect of energy development and production from indigenous resources reduces the pressure on fuel dependency which is depicted in **Figure 8-23.** In the case of Karnali Province, we cannot see much development in the ratio of the fossil fuel import to the total energy ratio. This is not because there is no increase in petroleum import but the total energy drops by large due to improvement in energy efficiency. Thus, although there is improvement in energy dependency, we cannot see much difference in this resultant ratio.

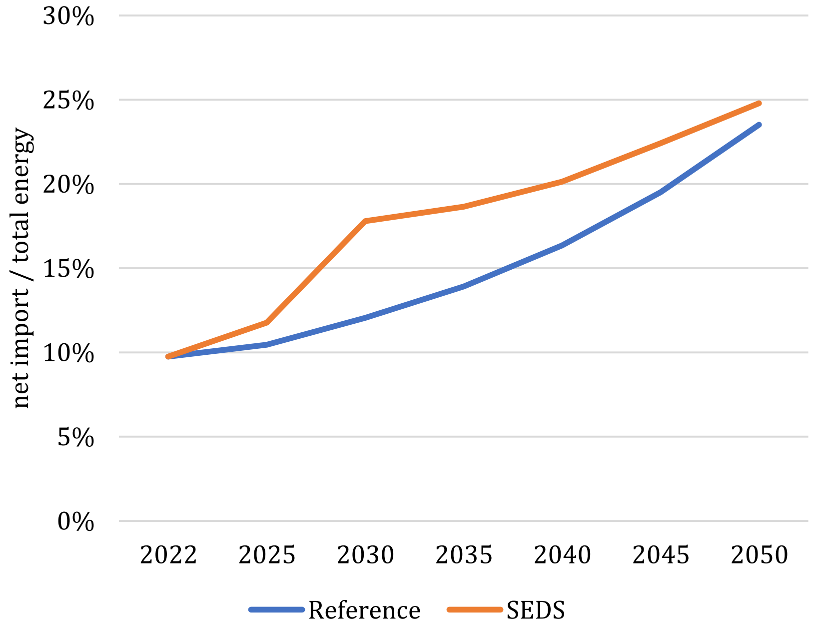


Figure 8-23. Petroleum Import to Total Energy Ratio in Karnali Province

Figure 8-24 shows the impact in GHG emissions due to policy interventions of clean energy. Emissions which were growing at the rate of 3.1% in the Reference Economic Growth Scenario would increase at the rate of only 0.4% resulting in the GHG emissions reduction of 38% in year 2030 and up to 53% in year 2050. This reduction in GHG emissions is not only beneficial for climatic reasons, but also for (a) health perspective – since use of carbon-based fuels emit other pollutants that directly affect health of local population and users, and (b) economic perspective -by monetizing the emission reduction by carbon trading.

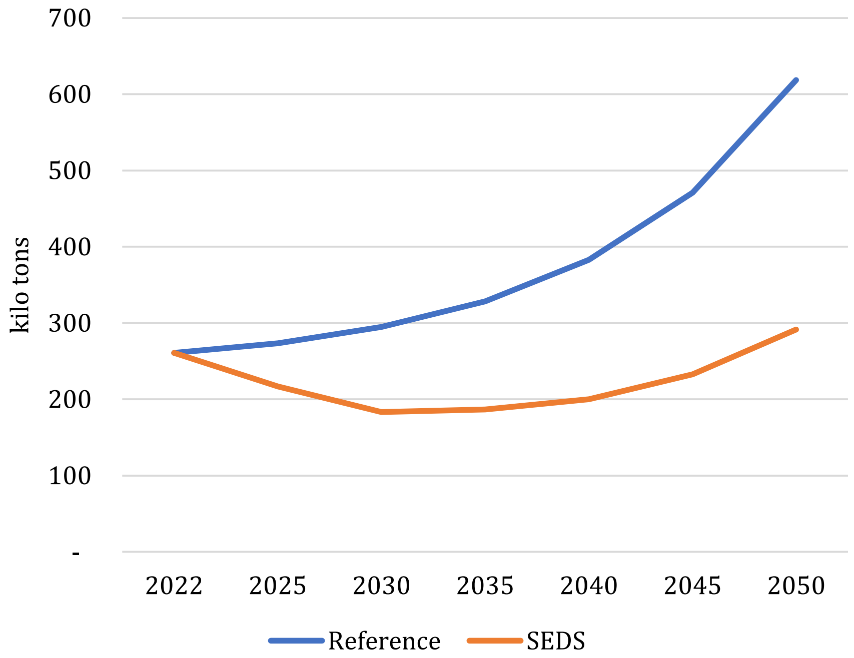


Figure 8-24. GHG Emissions in Karnali Province

To meet the larger share of the energy requirements in the SEDS and to achieve the development goals described above, the development of hydropower plants is essential. With respect to reference case, the installed hydro power plant capacity requirement in the SEDS would be about 146 MW in 2030 and 606 MW in 2050 The capacity requirements in SEDS in 2030 and 2050 are 3 times and 6 times of the installed power capacity requirements in the REF scenario as shown in **Figure 8-25.**

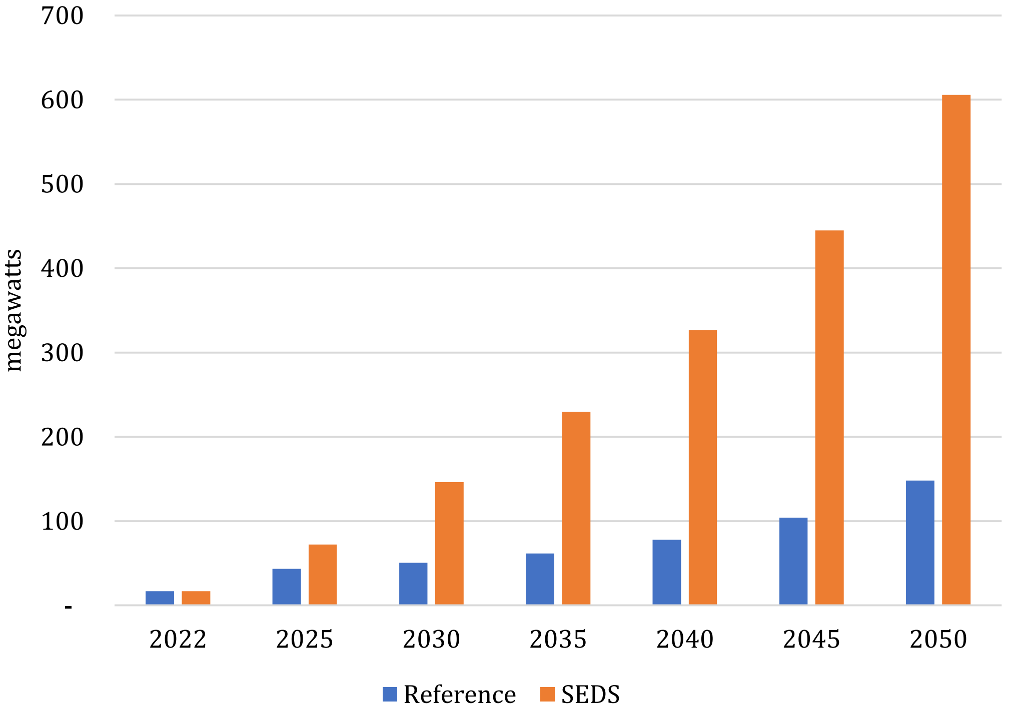


Figure 8-25. Hydro Power Plant Capacity Requirement in Karnali Province

8.3 Provincial Comparison

Comparing the energy consumption of Karnali Province with the rest of the province, the total consumption of the province is lowest among the seven provinces. One of the major reasons for low consumption in Karnali Province is the small number of economic activities, including industrial as well as commercial activities, compared to other provinces. Furthermore, the overall population of the province is also the lowest, causing a lower demand for energy. Moreover, the reliability of energy supply has also been a hurdle for increase in energy demand (**Figure 8-26**).

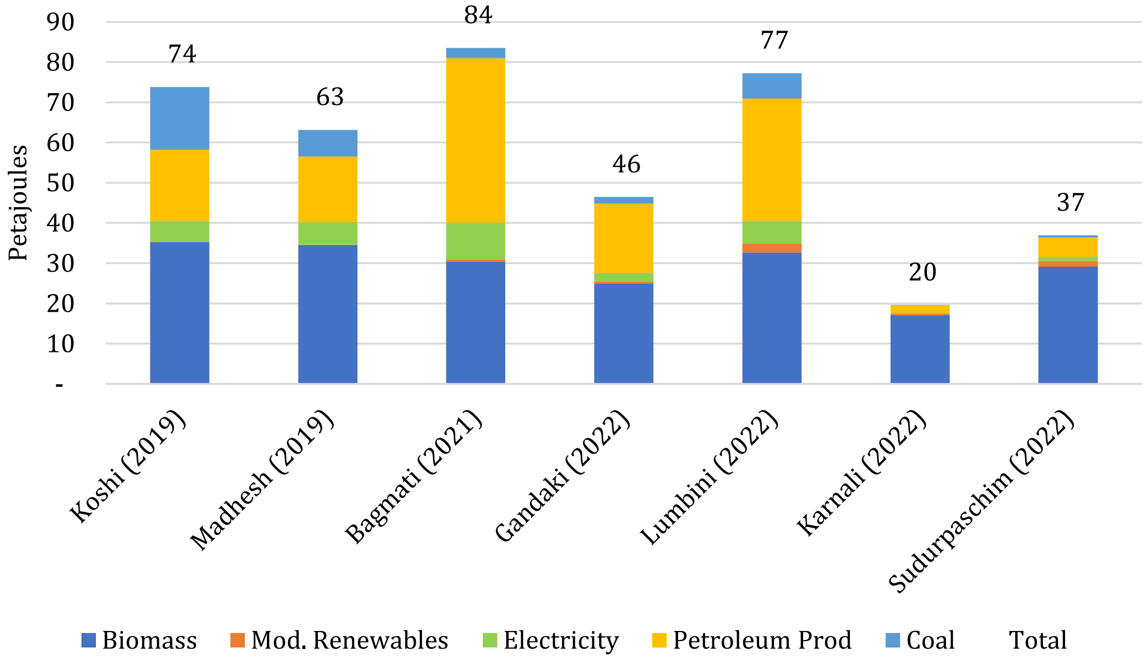


Figure 8-26. Provincial Comparison of Energy by Fuel Types

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, Karnali has the least industrial energy per GVA indicating lower energy-intensive industries in the province. Similarly, commercial energy per GVA of Gandaki province 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	14.50	11.30	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 Karnali 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 the current 1% of GDP to 15% by 2030, and to 18% till 2050. 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 hydropower development and industrial capital costs **Table 9-1.**

In the case of Karnali Province, which have huge natural resources and feasibility for development of hydropower plants, the province can invest in infrastructural development for power transmission as well as 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	0.10	1.62	2.47	3.37	4.36	5.51	7.09
Capital Investment as % of GDP	0.06 %	0.83 %	0.95%	0.94%	0.85%	0.72%	0.60%
Investment in the SEDS scenario in NR billion	0.10	14.48	39.30	66.34	95.96	129.10	167.78
Capital Investment as % of GDP	0.06 %	7.39 %	15.07 %	18.50 %	18.76 %	16.98 %	14.19 %

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 more than 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 38%, and 53% in 2050. This considerable reduction of GHG emission accounts for efficient and modern technology.

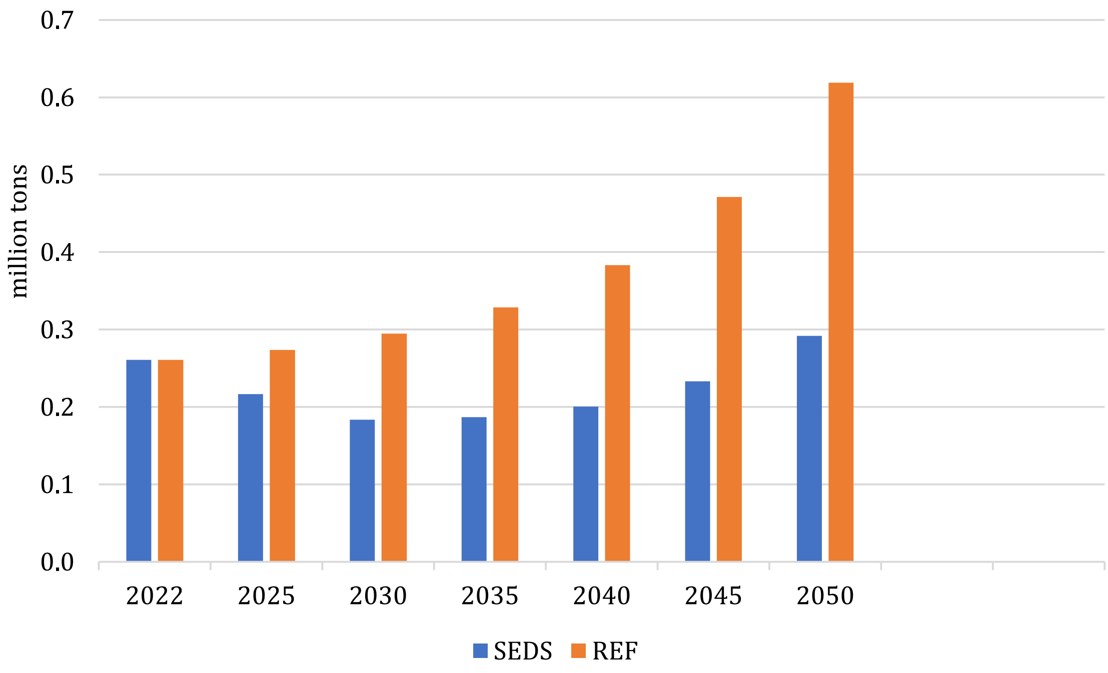


Figure 9-1. GHG Emission for Different Scenarios

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.

Table 9-2. Marginal Abatement Cost

	2025	**2030**	**2035**	**2040**	**2045**	**2050**
Incremental Investments (billion NPR)	13	37	63	92	124	161
GHG abated (kt)	57	112	142	183	238	327
MAC ('000 NPR/ton of CO2e)	226	330	444	501	519	491

The MACs on average are in the range as calculated for other developing countries (Wang et. al, 2022).

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 huge under the SEDS scenario counting over 2.5 billion NRs in 2030 and 25 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 7% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute 15% of the investment required.

This indicates a 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 matters highlight 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.

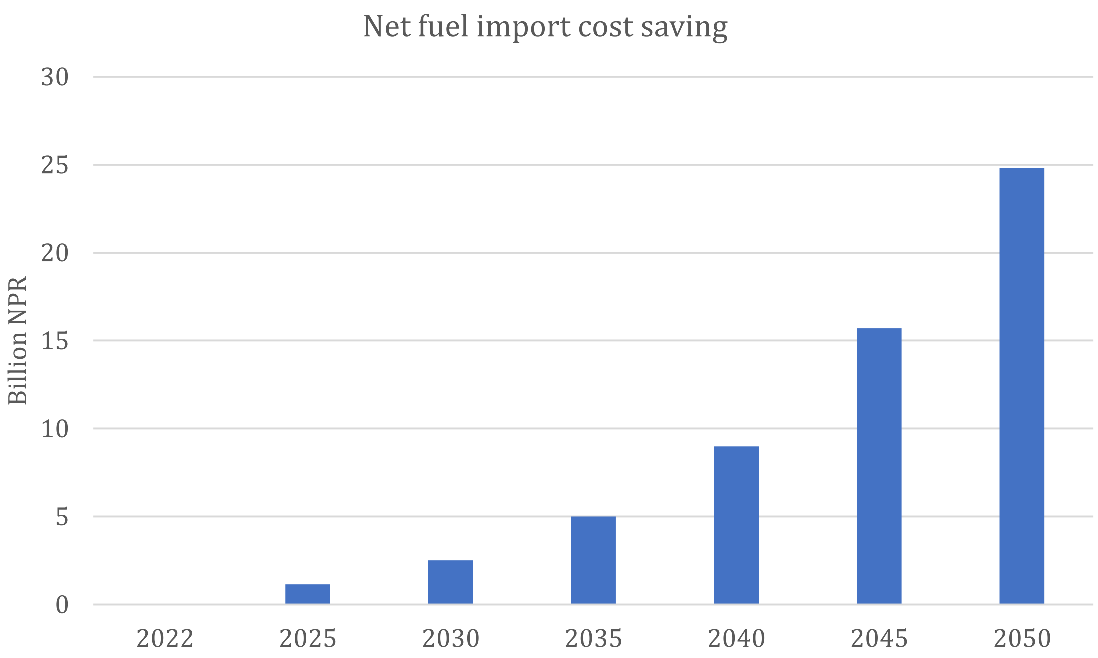


Figure 9-2. Net Fuel Import Cost Savings

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)	0.23	0.38	0.63	1.13	1.06	1.87

It is evident that net fuel import savings and amount earned by carbon certificate will not be sufficient for the capital investments required for the province. Hence, the federal government must seek international climate funds for grants, loans from the international financial institutions, and domestic private financial sources for the energy transition in the Karnali Province.

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 households; 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, much 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 a 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 entities are not locally based and/or bring 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.

11 Conclusion and Policy Recommendations

In the context of Nepal and especially in the Karnali Province, energy planning and research are critical for socioeconomic development. Karnali Province has the highest energy poverty compared to other provinces. The updated database on the energy sector is essential for energy planning and energy policy development. The database highlights key issues that need to be addressed at the provincial levels, primarily the changing energy demands and challenges in adopting an environmentally friendly energy supply. The updated database on the energy sector is very vital as energy sector is the foundation for the socio-economic development in the Karnali Province. The overarching goal of this report is to help in formulating energy security and facilitating economic development, promoting environmental sustainability, mitigating climate change, and expanding rural electrification.

The study is related to energy consumption determined through primary sample surveys and the energy supply situation is based on secondary resources in the Karnali Province. It has focused primarily on 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 the residential sector is taken as population. In addition to that, a situational analysis of macroeconomic indicators of Karnali Province and socio-economic analysis in the residential sector based on the survey has been carried out.

In the year 2021/2022, the primary sample survey shows that the total final energy consumption of the Karnali Province was 19.6 PJ which accounts for 12 GJ per capita. This energy consumption per capita seems to be slightly lower than the national average from previous studies. The shares of energy consumption in economic sectors of the Karnali Province indicate some differences from the national level energy consumption pattern. Residential and Commercial sectors consume 86% and 6% of total energy consumption respectively in 2022. The share of energy consumption in the industrial sector, compared to the national level, is lower in the province. Transport sector consumption is at 5% and the consumption for the industrial sector is nominal at 2% in 2022. The final energy consumption in the agriculture sector stands at 1%, which is on par with the national level from the previous studies. As for energy consumption by fuel types, the use of biomass is very high at around 87%. Petroleum products comprise 10% of the total energy consumed in the province, coal is 0.3%, and electricity is 1%. Modern renewables account for 2% of the total energy and they are mostly from biogas plants.

As per ecological regions, Karnali Province has two regions – Hills, and the Mountain region. The Hilly region has the highest energy consumption with 60% of the total consumption in the province, which is followed by the Mountain region with 31%, and the rest is consumed in the transportation and construction, and mining sectors, at 5% and 1% respectively. The Hilly and Mountain regions both consume fuelwood as a source of energy in above 80% of all households. Fossil fuels and electricity consumptions in the Hilly region are higher which is understandable because of the concentration of goods and services within the region.

Despite the region's significant hydropower potential, the energy supply remains inadequate and also faces challenges in expanding its energy infrastructure, particularly in remote areas, due to difficult terrain and inadequate investment. To address these challenges, the government has prioritized increasing access to modern off-grid energy services, improving energy efficiency, and developing renewable energy sources such as hydropower, solar, and wind. Efforts are also underway to promote energy conservation and to expand transmission and distribution networks to rural areas. However, significant investments and policy reforms will be needed.

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.

In the REF scenario, primary solid biomass occupies 87% in 2022, which is expected to be reduced to 65% of the total energy demand in 2050. It indicates that due to rampant energy poverty, solid biomass will still be prevalent in the energy demand if proper policy measures are not implemented. Petroleum products will jump from 10% in 2022 to 22% in 2050. Grid-electricity will be just 3% of the total energy demand in 2050, whereas modern renewables are expected to reach 8% of the total energy demand and off-grid Distributed Energy Resources (DER) will have a priority due to difficult topography of the province. The installed capacity of power plants in 2050 will be 148 MW. Per capita electricity demand will reach 446 kWh in 2050 which is 3 times lower than the values stipulated in the NPC’s roadmap for achieving SDGs by 2030. GHG emissions per capita will reach 301 kg in 2050.

With the combined policy measures undertaken, SED scenario shows some promising aspects of sustainable energy development in the Karnali Province. The total energy consumption in 2050 is lower than the values in 2022 with the focus on electrification, energy efficiency and clean energy technologies. The share of primary solid biomass declines to 28% of the total energy demand in 2050. Electricity demand attains 31% in 2050, whereas petroleum products occupy 24%. Modern renewables reach 16% in 2050. The installed capacity of the power plants is expected to reach 606 MW in 2050 and per capita electricity will reach 929 kWh in 2050 which is still lower than the value as stipulated in the NPC’s roadmap for achieving SDGs in 2030. GHG emissions per capita will be 142 kg in 2050 and it is half of the value in the REF scenario in 2050.

Policy Recommendations

Electrification should be the first and foremost priority in all economic sectors.

- **Energy Generation Capacity Development**

  In Karnali Province, although current electric generation capacity exceeds demand, future projections anticipate a significant increase in demand as sustainable energy goals are pursued. While ongoing and planned projects offer support, they may not meet long-term needs. Thus, the province must prioritize expanding electricity generation capacity. In the short term, attention should focus on boosting distributive generation systems and rehabilitating MHPs to address immediate needs. Long-term strategies should emphasize expanding hydropower capacity, leveraging the region's abundant water resources. Integrating utility-scale renewable energy plants like solar and MHPs can enhance energy resilience. By investing in diversified generation infrastructure, Karnali Province can achieve greater electricity sufficiency and reliability.

- *Actors: Ministry of Physical Infrastructure and Urban Development – Karnali Province; Ministry of Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat; Nepal Electricity Authority – Karnali Province*

- **Energy Infrastructure Development**

  In Karnali Province, where electricity access and road infrastructure are lacking, prioritizing energy infrastructure is crucial. The province faces challenges in both electricity access and reliability, especially in remote areas. To tackle this, substantial expansion and upgrades to electricity infrastructure are necessary to improve accessibility and reliability, boosting consumer confidence and demand. Additionally, expanding road infrastructure is vital for accessing modern services, fostering economic growth, and enhancing residents' quality of life. By investing in energy and road infrastructure, Karnali Province can unlock its potential for sustainable economic growth and development.

  - *Actors: Ministry of Physical Infrastructure and Urban Development – Karnali Province; Ministry of Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center; Nepal Electricity Authority – Karnali Province*

- **Clean Cooking Promotion**

  In Karnali Province, where clean energy access is limited and fuelwood is predominantly used for cooking, promoting clean cooking alternatives is vital. Currently, there is low adoption of clean cooking technology, presenting an intervention opportunity. In the short term, incentivizing residential as well as commercial sectors to adopt eCooking can initiate a shift towards cleaner cooking practices. Meanwhile, efforts to expand electricity access, raise awareness, and enhance technological capacity can pave the way for widespread electrification of cooking in the long term. eCooking offers benefits like reduced environmental impact, increased electricity demand, decreased reliance on imported LPG, and improved cooking efficiency. By prioritizing clean cooking promotion, Karnali Province can enhance public health, reduce deforestation, and foster sustainable development, while creating economic opportunities and advancing electrification goals.

  - *Actors: Ministry of Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center; Nepal Electricity Authority – Karnali Province*

- **Electricity Demand Creation**

  In Karnali Province, where economic activity is limited and access to the national grid of electricity is sparse, there exists a unique opportunity to stimulate demand for electricity. Despite excess electricity production nationwide during wet seasons, Karnali Province's lower energy consumption signifies untapped potential. By incentivizing demand creation, particularly in agricultural activities, industries, commercial sectors, and transportation, the province can catalyze economic growth and elevate its overall status. Additionally, targeting the residential sector for increased electricity usage can further bolster demand. Moreover, addressing challenges such as low reliability of electricity supply and geographical remoteness will be critical in fostering a conducive environment for demand creation initiatives. Through strategic interventions, Karnali Province can harness electricity demand as a driver of development, unlocking opportunities for prosperity and advancement.

Actors: Ministry of Land Management, Agriculture & Co-operative – Karnali Province; Ministry of Industry, Tourism, Forest and Environment – Karnali Province; Ministry of Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat; Nepal Electricity Authority – Karnali Province

- **Energy Efficiency Regulations**

In Karnali Province, energy demand is relatively low, but increasing it is vital for economic growth. While boosting energy-intensive activities, it's 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, Karnali Province can optimize its energy use, spur economic development, and contribute to a greener future.

Actors: Ministry of Physical Infrastructure and Urban Development – Karnali Province; Ministry of Industry, Tourism, Forest and Environment – Karnali Province; Ministry of Water Resources and Energy Development – Karnali Province; Karnali 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. 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 Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center

- **Renewable Energy Commercialization**

The findings reveal an alarming trend of underutilization and inefficient use of renewable energy sources in the province, notably biomass. Despite its abundance, biomass is mainly used in traditional open stoves, leading to health hazards, environmental damage, and resource depletion. This non-productive energy use calls for urgent intervention. Transitioning to clean energy alternatives like improved cookstoves or biogas systems presents a significant opportunity to commercialize the forest sector as an energy resource for industries and other economic sectors. This shift addresses health and environmental concerns while creating markets for renewable energy technologies, promoting sustainable development, and mitigating traditional biomass's adverse impacts.

- *Actors: Ministry of Industry, Tourism, Forest, and Environment – Karnali Province; Ministry of Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat*

- **Database Management**

  Effective database management is crucial for informed decision-making in energy planning and policy formulation. A comprehensive database acts as evidence and a benchmark for developing strategies. It's recommended to establish a reliable system covering all energy aspects, providing stakeholders with accurate, up-to-date information. Provincial governments should proactively set up database management systems, utilizing the National Energy Information System (NEIS) and provincial reports. These systems streamline data collection, storage, and analysis, enabling evidence-based decisions and promoting transparency and accountability.

  - *Actors: Ministry of Water Resources and Energy Development – Karnali Province; Karnali Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat; Nepal Electricity Authority – Karnali Province*

- **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: Alternative Energy Promotion Center; Provincial Center for Good Governance; Local Government – Karnali Province*

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