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Water and Energy Commission Secretariat
Singha Durbar, Kathmandu
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Final Report

(Gandaki Province)

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

April 2024

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Acronyms

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

MOEWRI	Ministry for Energy, Water Resources, and Irrigation
MoF	Ministry of Finance
MOPE	Ministry of Population and Environment
MSW	Municipal Solid Waste
MT	metric tons
MW	Mega Watt
NACEUN	National Association of Community Electricity Users-Nepal
NDC	Nationally Determined Contributions
NEA	Nepal Electricity Authority
NECC	National Electric Cooking Campaign
NOC	Nepal Oil Corporation
NPC	National Planning Commission
NRB	Nepal Rastra Bank
NSIC	National Standard Industrial Classification
NSO	National Statistical Office
NPHC	National Population and Household Census
ODK	Open Data Kit
PSF	Primary Solid Biomass Fuels
PSU	Primary Sample Unit
REF	Reference Economic Growth (Scenario)
RET	Renewable Energy Technologies
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for All
SEDS	Sustainable Energy Development Scenario
SHS	Solar Home System
SPVPS	Solar Photo Voltaic Pumping System
SREP	Scaling Up Renewable Energy Program
TJ	Tera Joule
ToE	Tons of Oil Equivalent
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
W2E	Waste to energy
WB	World Bank
WECS	Water and Energy Commission Secretariat
YOY	Year Over Year

Executive Summary

Global and National Energy Review

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

The global energy sector has been moving towards renewable energy at a faster pace than ever. After the COVID - 19 pandemic and regional energy crises, energy production from renewables is strongly moving forward. Renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records. The World Energy Outlook 2021 points out that the new energy economy will be more electrified, efficient, interconnected, and clean. However, the report also suggests that the speed of change in energy can be countered by another showing the stubbornness of the status quo – the main reason being uneven economic recovery from last year's Covid-induced recession.

Escalation of conflict in Ukraine in the fourth quarter of 2022 and geopolitical situation in the Middle - East region in 2023 may drastically curtail oil and gas deliveries from Russia to western Europe, China, and India, and from the Middle- East region, creating structural uncertainty in the petroleum and coal markets. As such, oil importing countries like Nepal which depends even on import of electricity from neighboring country in dry season are at a very precarious situation since most of the power plant in India and other countries are based on fossil fuels.

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. 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.

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 and to estimate 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 (Mountain, Hills 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 based on available secondary data/information.
- Prepare the most appropriate and relevant models for energy demand forecast.
- To identify the costs of all energy resources in each economic sector in each sample unit.
- To analyze and report per capita and per economic sector energy consumption for different economic sectors and physiographic regions based on different growth rates.

Scope of the study

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

- Before conducting the survey on energy consumption, supply situation and demand projection, the existing plans, policies, rules, regulations, and guidelines related to energy were reviewed.
- Primary data was collected at physical and local unit (eg. bhari) at first and then converted into standard gigajoules (GJ) and Ton of Oil Equivalent (ToE) unit later during analysis.
- Methodology of energy demand analysis for each economic sector was developed by the consultant and was implemented after approval from the WECS.
- Total and Specific energy consumption of all districts of each Province in all economic sectors by each fuel type, end uses, and energy technologies/devices used were provided.
- Energy supply and demand of each Province at different physiographic regions and with different growth scenarios in all economic sectors were determined.
- The potential of all types 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 demand of each Province at different physiographic regions (Hill, Mountain and Terai) for all economic sectors and with different growth scenarios up to 2050 AD were forecasted by using freely available software/model
- All the energy resources available and used in the country were considered while surveying the energy consumption, demand, and supply status. All the energy resources used in all economic sectors for all purposes and end uses by all devices were identified during the survey.
- For determination of sample size, all existing data of each economic sectorwas collected from the latest reports of concerned authorities.
- A detailed survey questionnaire for each economic sector was prepared separately by the consultant and a samplesurvey was carried out only after the questionnaire has been approved by the WECS. The questionnaire would also address the peak and the off-peak time of energy consumption.
- Before conducting the Energy Consumption, Supply and Demand survey, a training program for the enumerators, field supervisors and WECS staffwas 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 includethe name and contact number of concerned persons of the concerned institutionsand was submitted to WECS after completion of the field work in Field/Interim report.

Gandaki Province

Gandaki Province borders the Tibetan Autonomous Region of China to the north, Bagmati Province to the east, Karnali Province to the west, Lumbini Province, and Bihar of India to the south. The total area of the province is 21,504 km², which is 14.57% of the country's total area. In terms of terrain, the province is spread over the Himalayan, Hilly, and Terai regions. Gandaki Province encompasses a total of 11 districts, one metropolitan city, 26 municipalities, and 58 rural municipalities.

As much as 96.21% of the population has access to electricity in the province. Gandaki Province generates 565 MW of hydroelectricity. According to NEA, the highest sales revenue of electricity sales is from the domestic sector (44%) followed by the industrial sector (25%). The loss of electricity in the province was estimated at 9.10% for the year 2077/78.

Table 1 Briefly Highlights the Socio-economic Status of Gandaki Province.

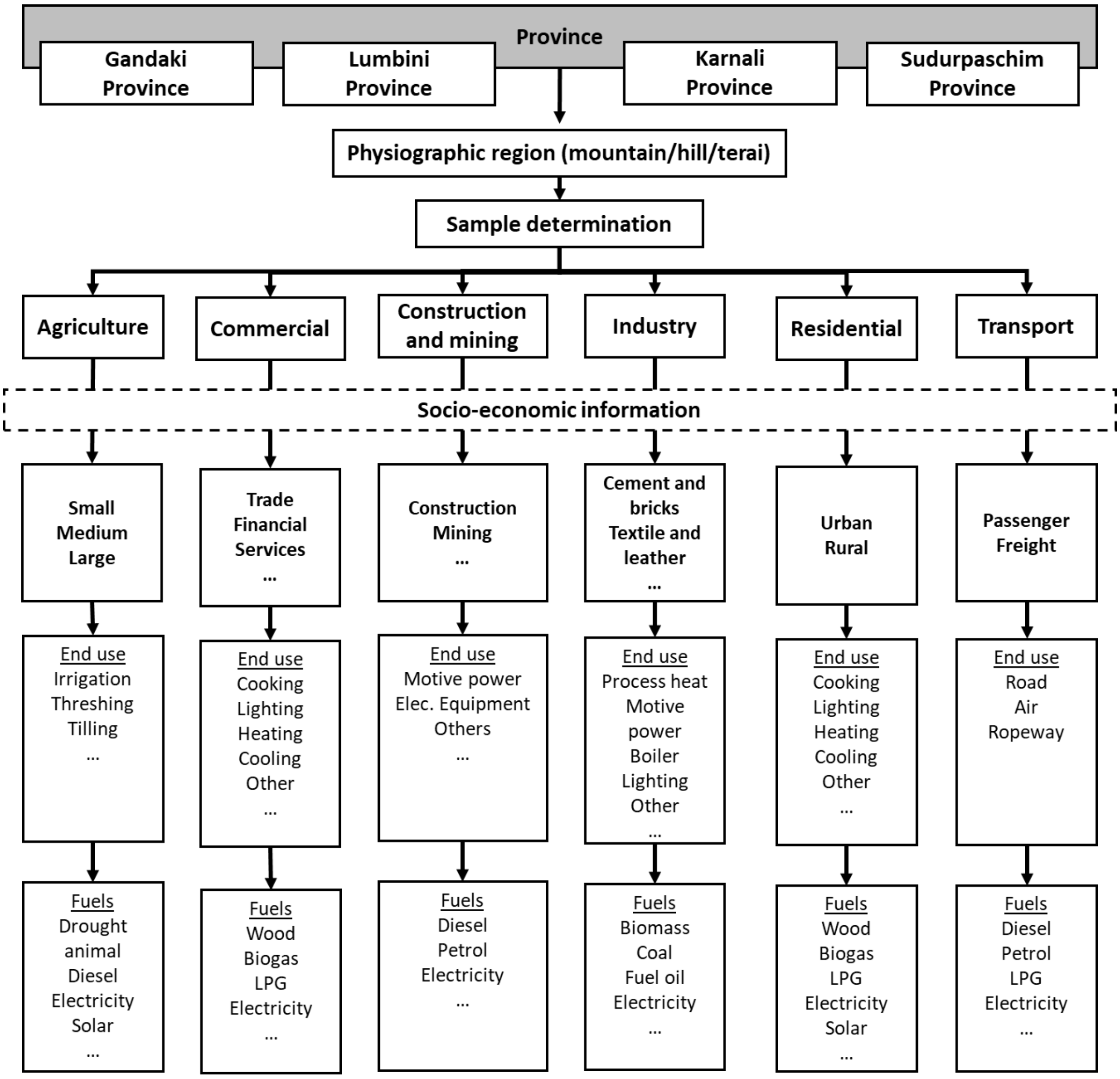
Table 1. Provincial Economic and Social Indicators of Gandaki Province

Indicators	Nepal	Gandaki
Administrative and population situation[1]		
No. of local level	753	85
Population (%)	100	8.49
Area (%)	100	15.3
Economic and Social Sectors		
Economic growth at consumers' prices (%)[1]	5.84	6.17
Gross Domestic Production		
Provincial contribution to GVA (at consumers' prices)	100	8.9
Per capita GDP (in US $)[1]	1,372	1,437
No. of registered industries[2]	8,656	798
No. of cottage and small industries[2]	555,776	59,980
Investment in industry (in Rs. billion)[2]	2,512.1	548.7
No. of registered companies[3]	283,358	15,724
hydropower production (MW)[4]	2,023	565
Forest Area (%)[5]	100	12.36
Local road network (KM)[6]	64,617	11,570
No. of Schools[7]	34,368	3,987
Financial sector[8]		
No. of branches of bank and financial institutions	11,349	1,405
Population per branch (no.)	2,572	1,765
Branch of Insurance companies (No.)[9]	2,905	321
Provincial expenditure (in Rs. 10 million)[10]	18,883	2,562
Provincial revenue (in Rs. 10 million)[10]	8,794	973

Methodology for study

The methodological approach was conducted systematically identifying the steps in collection, analysis, and synthesis of information from different sources.The basic disaggregation for the sample survey 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 Gandaki 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 Gandaki 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 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 wereconsidered 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 has been used to develop a base year energy model with inclusion of socio-economic parameters. Based on predicted demographic and economic parameters, the energy scenarios have been developed at the provincial level that include –

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

The energy scenario development has been a two-step process. Firstly, Model for Analysis of Energy Demand (MAED) is used for energy demand projection.Secondly the TIMES model has been used, that includes demand projection as well as the supply and emission analysis.

Energy Supply Situation in Gandaki Province

Solid Biomass Energy

Biomass, the total of non-fossil organic material derived from biological sources, is the most important source of renewable energy in the world. The main use of Nepal's forests is to provide biomass to satisfy the need of domestic fuel. Fuelwood is used for several purposes like cooking, heating, and other thermal purposes in several processes in domestic, commercial as well as industrial uses. The demand for fuelwood in the country has rapidly increased due to population growth in the past and has resulted in tremendous pressure on existing forests. Local community bring hundreds of cycle - loads of fuelwood to their villages from forests in rural area But, due to migration of population into towns and employment abroad, rural population has decreased in recent years, and there is a transition to LPG in cooking as well with the result of burgeoning double-digit growth in imports of LPG in the country. Thus, annual fuelwood from the whole Gandaki Province is 1,925,061 m^3 (This is harvestable quantity). This volume accounts for 11 categories, 10 defined species and 1 other (miscellaneous). Thus, the totaled final fuelwood comes to around 1,369 kilo tons. The potential biogas in Gandaki Province is 170 PJ. Total potential energy produced from waste is 28,342 TJ.

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 2).**

Table 2. Petroleum Products consumption in 2077-78 in Gandaki Province

Districts	MS	Diesel	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Baglung	1,468	4,967	101	-	-
Gorkha	1,504	6,376	-	-	-
Kaski	23,903	38,374	1,307	1,326	-
Lamjung	991	4,667	-	-	-
Mustang	-	72	-	-	-
Myagdi	794	4,620	-	-	-
Parbat	1,357	6,818	-	-	-
Syangja	3,353	11,785	326	-	-
Tanahun	7,816	30,589	16	-	-
	41,186	**108,267**	**1,750**	**1,326**	**-**

(NOC, 2022)

LPG consumption cannot be ascertained from the NOC database as LPG sales crisscross from districts to 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 (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).The hydropower potential of Gandaki is 15,000 MW which is around 21% of the overall national potential.As per NEA, the electricity sales are 2,279 TJ (633 GWh) in 2022.

Modern Renewables

There are 7 MW of micro- hydro power plants, 48,373 SHS and 391 kW of institutional solar photovoltaic systems. There are also 107,000 mud ICS and 23,000 metallic ICS installed in Gandaki Province.

Energy Consumption in 2022

The total final energy consumption (FEC) in Gandaki Province from the sample survey was found to be 46.462TJ in 2022. Among the six sectors, the residential sector is the highest energy-consuming sector followed by industrial sector. However, the amount of energy consumed in both the sectors is nearly equal.

Figure 2 and Figure 3 indicate the change in the consumption pattern in different economic sectors. With the residential and the industrial sectors being the highest energy-consuming sectors, the use of biomass and fossil fuels are prevalent in the energy mix.

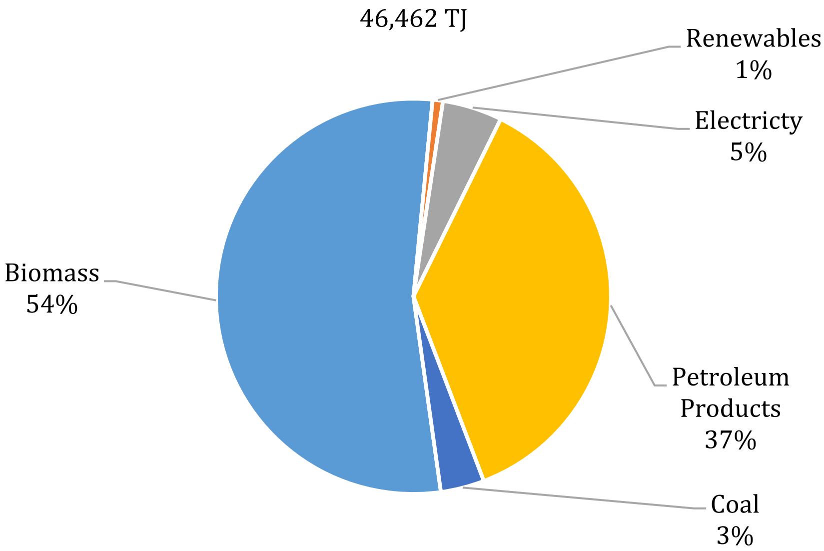


Figure 2. Energy Consumption Share in Gandaki Province by Energy Types

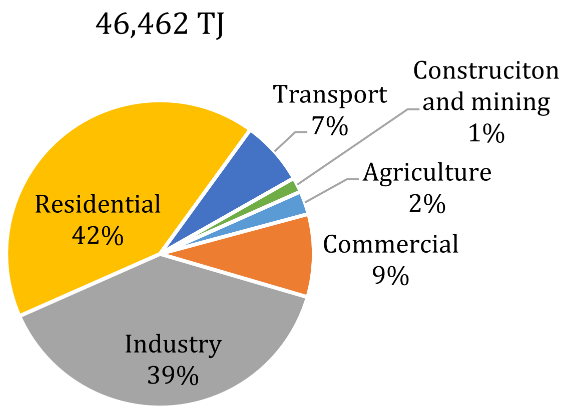


Figure 3. Energy Consumption by Sectors in Gandaki Province

Energy Flow in 2022

Figure 4 illustrates the flow of energy in Gandaki Province in 2022, which clearly indicates there is a higher probability of energy efficiency improvement and clean energy transition in residential land industrial sectors.

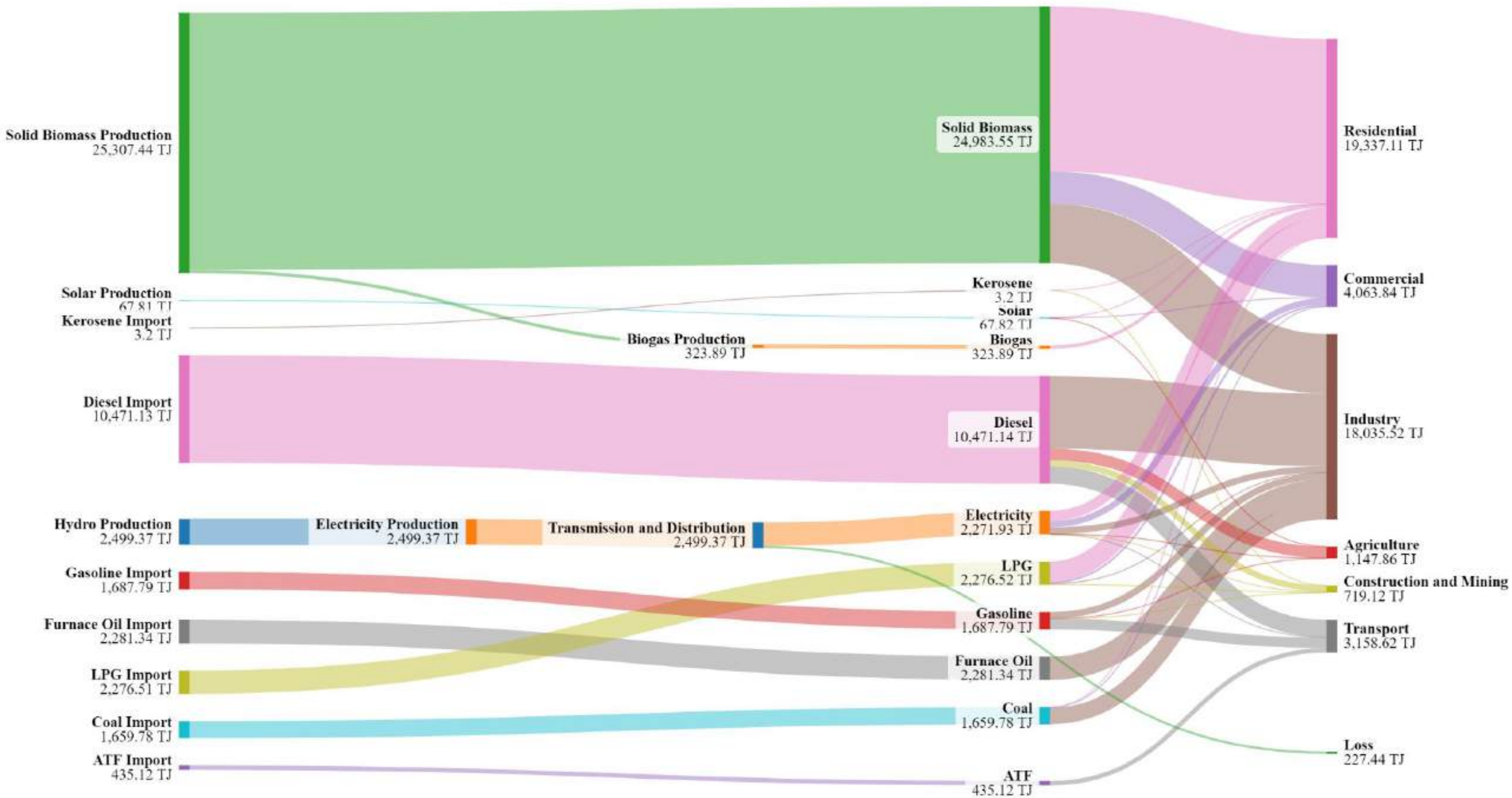


Figure 4. Sankey Diagram for Energy Flow in Gandaki Province

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 is also conducted. In the REF scenario, energy consumption reaches 56 PJ in 2030 and 177 PJ in 2050 respectively. In the SED scenario, the energy consumption attains 48 PJ in 2030 and 168 PJ in 2050 respectively.

Comparison between SED and REF scenarios indicates that per capita electricity in Gandaki Province reaches 6,729 kWh in 2050 in the SED scenario compared to 1,586 kWh in the REF scenario. Per capita GHG emissions decline to 1,381 kg in 2050 in the SED scenario, whereas it will be 2,918 kg in the REF scenario. Installed power plant capacity required reaches 8,000 MW in 2050 in the SED scenario. But it will be 1,900 MW in the REF scenario.

It is obvious in Figure 5 that in the absence of policies promoting clean and renewable energy, Gandaki Province will continue to rely heavily on biomass energy sources and even more on imported petroleum products in 2050. This will result in a significant surge in the demand for fossil fuels by 2050. Besides, the sustainability of a high demand for biomass energy from the region's forests is highly questionable. Additionally, there are concerns about whether the economy of Gandaki Province can maintain the long-term importation of such vast quantities of fossil fuels.

The Sankey diagram depicted in **Figure 6** illustrates a reduction in reliance on solid biomass and the limited importation of fossil fuels to meet essential demands, as presented in the SED Scenario by the year 2050. This transition in Nepal's energy landscape implies that electricity demand within the Gandaki Province predominantly derives from clean and renewable sources. This transformation not only bolsters energy security but also promotes sustainabilitywithin the region.

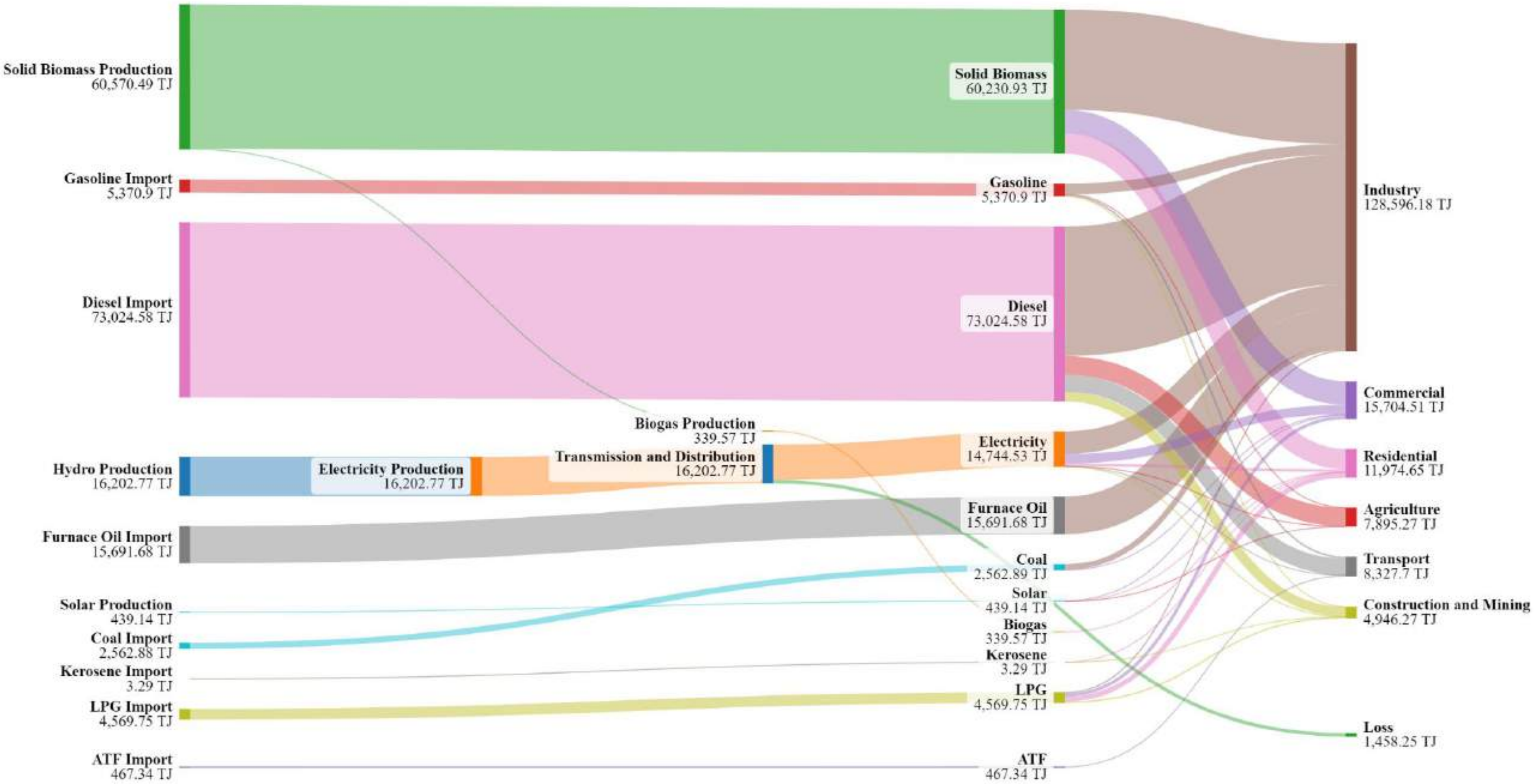


Figure 5 Sankey Diagram for Flow of Energy in Gandaki Province for the Reference Economic Growth Scenario in 2050

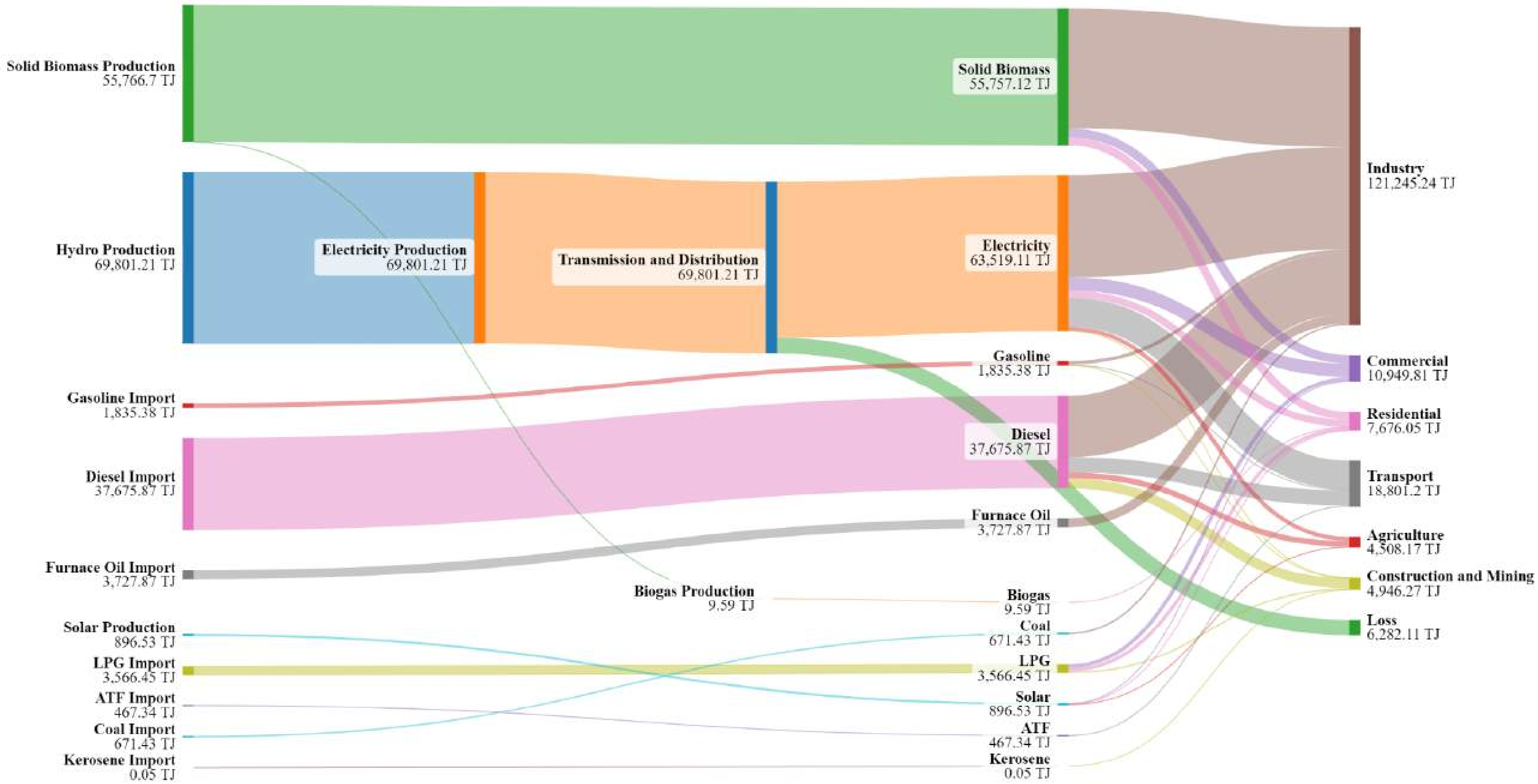


Figure 6 Sankey Diagram for Flow of Energy in Gandaki Province for the Sustainable Energy Development Scenario in 2050 (PJ)

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Gandaki Province indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and the sustainable energy development in the national context. This study also indicates that with the core focus on energy security, reliability, and sustainability, Gandaki Province/Nepal's energy development should be geared towards 5 energy transition aspects – (a) Sustainable Energy Development Policy, (b) Hydropower/renewable Energy Development, (c) Infrastructure Development, (d) Creation of Domestic Power Demand and Exploration of Power Markets in the South Asia, and (e) Reduction in Demands for Fossil Fuels.

1. Introduction

1.1 Background

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

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

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

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

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

1.2 Global Outlook

The world saw a global pandemic at the end of 2019. However, global energy consumption did see a dip. In the wake of the pandemic, however, energy production from renewables is takinga leap forward. Renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records (IEA, 2021). The World Energy Outlook 2021 points out that the new energy economy will be more electrified, efficient, interconnected, and clean. However, the report also suggests that the speed of change in energy can be countered by another showing the stubbornness of the status quo – the main reason being uneven economic recovery from last year's Covid-induced recession. Besides, events of recent years have accentuated the cost to the global economy of an energy system highly dependent on fossil fuels. Oil, gas, and coal prices have soared to new highs due toglobal disturbances which has much more adverse impacts on oil importing developing countries like Nepal (IRENA, 2022). Current escalation of conflict in the Eastern Europe in the fourth quarter of 2022 drastically curtailed oil and gas deliveries from Russia to western Europe, China, and India, creating structural uncertainty in the petroleum and coal markets (IEA, 2022).As such, oil importing countries like Nepal which depends even on import of electricity from neighboring country in dry seasonare ata very precarious situation since most of the power plant in India and other countries are based on fossil fuels.These events forebode catastrophe ahead in the world and foretell the need of nationsto be engaged without delay in accelerated energy transitional efforts to clean energy from renewable sources.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 morethan 80% reduction of emissions by 2030 (IEA, 2023b).

World Energy Outlook (IEA, 2018)[1] emphasized that energy is of paramount importance to human society and economic activity and so does the 2021 version – but it puts more focus on clean energy as the emissions have already pushed global average temperature of1.1 °C higher since the pre-industrial age (IEA, 2021). 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 pollutions that cause severe health problems around the world, especially in developing countries like Nepal. The energy sector is responsible for almost three-quarters of the emissions. Hence, it is of utmost importance for solutions to climate change. Energy features have prominence in the United Nations Sustainable Development Goals (SDGs), agreed upon by almost 200 nations in 2015. Nepal, in its roadmap for achieving SDGs by 2030(NPC, 2018), envisions a middle-income country in 2030 with vibrant, youthful middle-class people. To reach this

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

kind of status, Nepal needs an enormous consumption of energy resources based on renewable energy and energy efficiency for sustainable energy development and energy security in the country.

A recent report by World Wildlife Fund (WWF) in 2019(Lambrides, J.P. et. al, 2019)shows that nations need to focus their attention on low- carbon, low -cost and low- impact energy resources to limit global warming to 1.5^{0} C by the end of the twenty-first century. These kinds of energy resources are solar, wind, and low -dam or low -impact hydropower storage plants for flexibility and meeting the intermittency caused by variable energy resources like solar and wind. It means that developing nations must discourage the usage of fossil fuels and concentrate on renewable energy and energy efficiency for meeting their rising energy demand. But unfortunately, Nepal is becoming too much dependent on imported fossil fuels - imports of petroleum products against goods and services exports of Nepal have jumped from 59% in 2014 to above 90% in 2022[2] which has reflected in Nepal's poor balance of payment situation. Hence, for the development of a "Prosperous Nepal," it has become essential to have proper and dynamic energy planning of the whole energy systems in place at the local and provincial levels which need to be later integrated into the national energy systems planning for sustainable energy development and energy security in the country.

1.3 National Energy Scenario

The national energy demand has been seeing growth along with growth in population and economy – it is a common feature of the developing country. However, Nepal’s overall energy mix is still dominated by non-commercial energy sources. Although, as a result of Covid, the energy consumption saw a dip, mainly in the manufacturing sector, the total energy consumption of Nepal stood at 606 PJ in 2020 with an annual average growth rate of 4% maintained over the last decade (MoF 2021). As per the 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 very 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 and Madhesh and BagmatiProvincesby WECS in 2020 and 2022 supports also the transition in energy mix patterns by sectors.

Apart from the gradual energy transition, Nepal is actively working to increase access to clean energy options and increase the efficiency of energy use by taking strategic actions based on SDGs, LTS, and Second NDC documents. 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 areasindicate that at present it is more than 50% cheaper to cook on electricity than on LPG in Nepal (Nakarmi, 2022 - updated on 01September2023). 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

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

billion in 2021 – almost double fold in one year (NOC, 2022). These statistics amply highlight the vulnerability of economics of Nepal and energy security of the country.Notwithstanding all these happenings, Nepal is already in the fifth year of National Electric Cooking Campaign (NECC) in 2024 under the AEPC and other campaign partners like NEA, NACEUN, development partners, and national NGOs.At the local levels such as Lalitpur and Terai districts, local level governments are also distributing induction cooktops in subsidy to households.

In the current context, however, the primary source of energy in the residential sector remains to be fuelwood, agriculture residue, animal waste, biogas, and other biomass energy resources. Hydro electricity and solar energy are substituting traditional energy inurban 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 the Long-Term Strategies follow the Paris Agreement of 2015,the SDG7 and other goals, and the SE4ALL program targets to achieve universal access to affordable, reliable, and modern energy services, doubling the global rate of improvement in energy efficiency and increasing the share of renewable energy in the global energy mix by 2030 (UNDP, 2012; NPC, 2018). Currently, 75% of households (HHs) use solid fuels as a primary source of energy for cooking, and 18% use LPG. Access to electricity extends to 93% of HHs (NEA, 2021). However, the actual supply of electricity is inadequate, majorly due to lower capacity connection and reliability issues. Rural areas have access to 10% off-grid electricity that is used mainly for lighting and small electrical appliances. There was still above 12% of the population without electrification in Nepal (Adhikari, 2019; NEA, 2019). By the end of the fiscal year 2021/22, it is expected to reach 7% only (MoF, 2022). Solar home systems are taking a strong foothold in Nepal with the reduction of their global price per unit as well as readily available technology. However, the scope of solar energy is still limited to lighting. SDG7 targets 99% HHs access to electricity, shifting the use of fuelwood, and limiting the use of LPG by 2030 (NPC, 2018). It requires an installed capacity of 15,000 MW by 2030. To fulfill the targetthe government has already started its strategic action plan focusing on the development of the energy and power sector. Nepal has prepared the implementation plan for the Second NDC to achieve the goals of hydropower development, energy access, and clean cooking.

To elevate the current energy status of the country to that of developing countries, the first requirement is to develop a rigid and updated database of the energy demand, supply, and resource potential. Based on those, appropriate energy plans are to be formulated to achieve sustainable development and energy security in the country.

1.4 Energy Supply and Demand Situation in Nepal

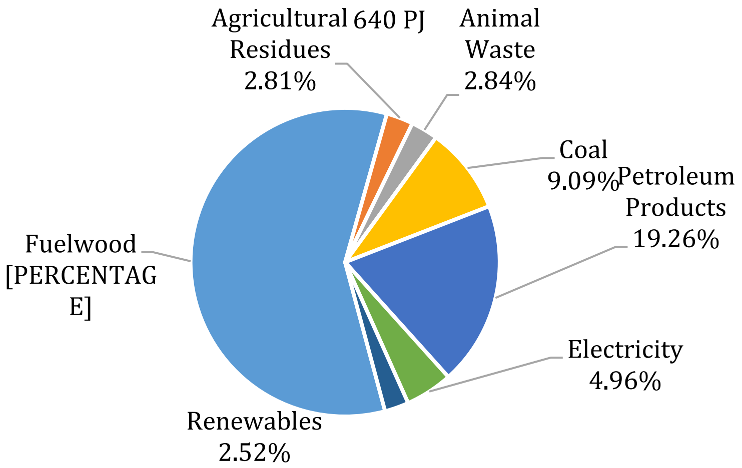
The overall energy consumption in Nepal reveals the dominance of the use of non-commercial energy sources. The total energy consumption of Nepal stood at 640 PJ in 2022 with an annual average growth rate of 2.3%YOY.Traditional energy consumption declined from 84% in 2010 to 64% in 2022 (WECS, 2023). However, the energy sources are still dominated by traditional sources (fuelwood, agricultural residues, and animal wastes). Nonetheless, there is a gradual shift to commercial energy sources (coal, petroleum products, and electricity) with an increase in the share of commercial energy from 15% in 2010 to 32% in 2021 at the national level, which recorded an increase of 12% growth per annum. There is a steady growth in renewable energy sources as well, with their share increasing from 1% in 2010 to 2% in 2021 (MoF, 2022). Meanwhile, the consumption of electricity has also lately increased to 5% from 2% a decade ago. The energy consumption by fuel type in 2021 is shown in **Figure 1-1.**

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

The recent provincial energy consumption and supply situation analysis completed for Koshi, Madhesh and Bagmati Provinces by WECS showed a shift in energy consumption patterns by sector. The detailed energy survey shows that KoshiProvince 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 largeshare in energy consumption of 15% which is primarily due to running of the International Airport in the Country at largest. Fuelwise, the share of petroleum product is highest in the province, wherein consumption of electricity is also very good at 10%. These differences in the energy consumption pattern of the three provinces are attributable to various factors, but majorly due to the availability and accessibility of resources as well as differences in the population and economic growth in the three provinces. The major source of energy in the residential sector is fuelwood, agricultural residues, animal waste, biogas, and other biomass sources. Hydro and solar energy sources have the potential to substitute these traditional energy sources in urban and rural households that use traditional energy sources for cooking and lighting. The industrial sector consumes coal, fuelwood, diesel, and electricity as major sources of energy with a 63% share of non-renewable energy consumption. Diesel, petrol, and ATF are 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 source in the commercial sector with a 34% share of non-renewable energy(WECS, 2014). The agriculture sector mainly uses liquid fuel for water pumping and farm machinery operations, where diesel is the major fuel in use.

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

The persisting impact of COVID-19 in Nepal over 2019-2020 led to a decline in energy consumption, mainly in production sectors. Petroleum products sales went down by 10% in 2019-20 compared to the value in 2018-19 while the electricity sale grew marginally by just 2% compared to the growth of 13% in 2018-19[3]. The growth in electricity use has risen again as COVID risk eased and industries begin to function to their capacity. Additionally, the increased access to electricity and the use of electric technologies have significantly increased the demand for electricity in the last 2 years (NEA, 2023).



(WECS,2023)

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

[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 Gandaki Province

Gandaki Province borders the Tibetan Autonomous Region of China to the north, Bagmati Province to the east, Karnali Province to the west,Lumbini Province, and Bihar of India to the south. The total area of the province is 21,504 km², which is 14.57% of the country's total area. In terms of terrain, the province is spread over the Himalayan, Hilly, and Terai regions. Gandaki Province encompasses a total of 11 districts, one metropolitan city, 26 municipalities, and 58 rural municipalities.

As per the 2021 census, the population of the province was 2.5 million (CBS, 2022). The population of the province is diverse. The economy of the province is largely dependent on farming, but tourism has a significant share in the economy and creates employment opportunities for the population. Nine out of 11 districts of Gandaki Province are connected via blacktopped roads. Road connections to Mustang and Manang, although navigable, are earthen and graveled, and connectivity becomes a serious issue in the rainy season.The major contributing sector to its GDP is the service sector and the least contributing sector is industry. The composition of the provincial GDP shows that it has a service-led economy. Tourism is the major service sector of this province.

So far administrative and population situations are concerned, Gandaki Province covers 15.3% of the total area with 85 local levels and 8.49% of the total population is residing in this province. Forest covers 12.36% of the total land area of the country. The local road network in this province has extended now to 11,570KM (17.9% of the national total road network). The number of schools is 3,987 (11.6% of the national total). 27.9% of the total hydropower (565KW) was produced in this province. Rs. 548.7 billion have been invested in 59,980 industries in the province (**Table 1-1and Figure 1-2**).

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

Indicators	Nepal	Gandaki
Administrative and population situation[1]		
No. of local level	753	85
Population (%)	100	8.49
Area (%)	100	15.3
Economic and Social Sectors		
Economic growth at consumers' prices (%)[1]	5.84	6.17
Gross Domestic Production		
Provincial contribution to GVA (at consumers' prices)	100	8.9
Per capita GDP (in US $)[1]	1,372	1,437
No. of registered industries[2]	8,656	798
No. of cottage and small industries[2]	555,776	59,980
Investment in industry (in Rs. billion)[2]	2,512.1	548.7
No. of registered companies[3]	283,358	15,724
hydropower production (MW)[4]	2,023	565
Forest Area (%)[5]	100	12.36
Local road network (KM)[6]	64,617	11,570
No. of Schools[7]	34,368	3,987
Financial sector[8]		
No. of branches of bank and financial institutions	11,349	1,405
Population per branch (no.)	2,572	1,765
Branch of Insurance companies (No.)[9]	2,905	321
Provincial expenditure (inRs. 10 million)[10]	18,883	2,562
Provincial revenue (inRs. 10 million)[10]	8,794	973

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.

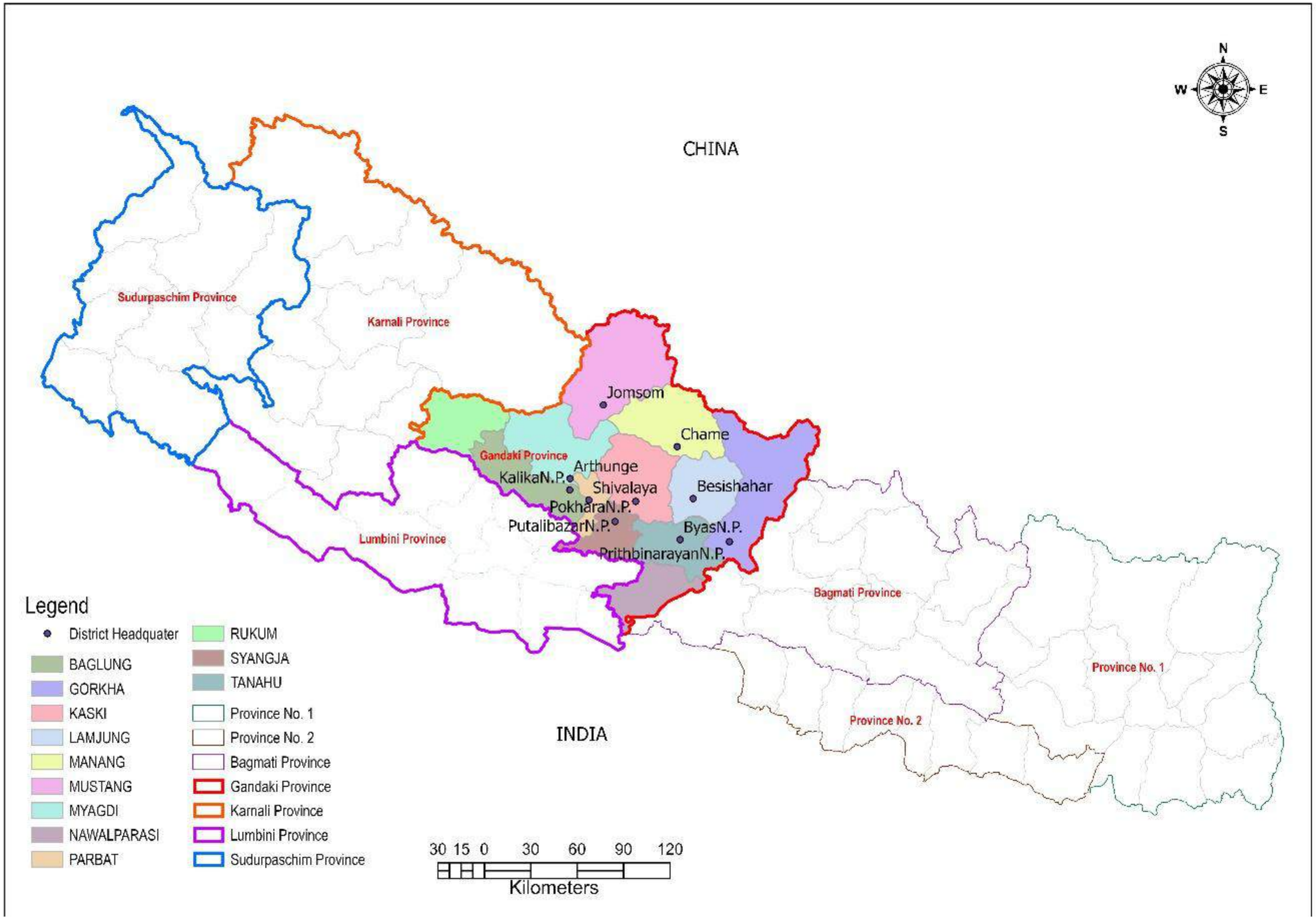


Figure 1-2. Gandaki Province

As much as 99.25% of the population has access to electricity in the province (NEA, 2023). Gandaki Provincehad a generation capacity of 565 MW of hydroelectricity (MoF, 2022). According to NEA, the highest sales revenue of electricity sales is from the domestic sector (45%) followed by the industrial sector (25%). The loss of electricity in the province was estimated at 8.47% for the year 2077/78.

Alternative Energy Promotion Centre (AEPC) has been promoting renewable energy technologies in Nepal to raise the living standard of the rural people and protect the environment. As of 2021, it has been able to implement 1,851 nos. of mini and micro hydro projects generating 34.47 MW of electricity among which, 371 nos. of projects are implemented in Gandaki Province generating 7.14 MW of electricity benefitting 67,359 nos. of rural households. Baglung and Gorkha have comparatively more beneficiary households covering 50.37% and 15.62% of the total provincial beneficiary while Mustang had not benefitted at all. According to AEPC, 204 nos. of improved water mills, 48,372 nos. of solar home system units, 223 nos. of institutional solar PV System generating 391.53 kWp, 50 solar irrigation systems, and 27 solar water pumping systems has been installed which covers 1.8%, 6.1%, 7.3%, 2.3% and 14.4% 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, around 13% of the installation has been done in Gandaki Province, i.e, 79,755 Nos. of domestic biogas plants, 106,802 mud ICS and 22,701 metallic ICS**.**

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

1.6.1 Policy and Strategy Overview

- **NDC Implementation Plan 2023**

GovernmentofNepal(GoN)submitteditssecondNationallyDeterminedContribution(NDC) forthe years2021-2030 in December2020. NDC 2020 has set the quantitative and policy-related mitigation targets along with the implementation priorities. This NDC implementation plan is developed to effectively implement the NDC targets in different sectoral and sub-sectoral areas with activity monitoring indicators, timelines, and required resources for the implementation.

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

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

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

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

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

- **Second Nationally Determined Contribution, 2020**

The Government of Nepal - Ministry of Population and Environment, in December 2020, communicated its Second NDC to the UNFCCC as a national pledge to contribute to the promotion of renewable energy services across the country. In the recently submitted NDC, GoN emphasized clean energy generation as well as replacing conventional technologies with modern and environmentally friendly energy technologies. On energy generation fronts, an increase of national hydropower generation from the existing 1400 MW to 15,000 MW by 2030 has been emphasized of which 5-10% will be generated from renewable electricity generation options such as mini and micro-hydro, solar, wind, and bioenergy. Electrification in the transport sector and replacement of conventional stoves with electric and improved cook stoves in the residential sector are also highlighted. The climate change 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 fossilfuel 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 1,500kWh 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 3000MW 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 10,000MW in the coming ten years.The government plans to generate 200MW of solar power from Madheshprovince, 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

Key Plans, Policies, programs	**Features**
Solid Waste Management Act (2011)	• A legal provision is providing responsibility to the Local Body for solid waste management. • Partnership with the private sector, community and non-governmental organizations, and local body • Instruction for segregation of solid waste at source, and promotion of 3R principles. • Permission for the private sector to develop and operate sanitary landfill sites, following EIA and IEE. • Legal provision to form Solid Waste Management Council • Provision to establish a Solid Waste Management Technical Support Center
Industrial Policy (2011)	• Provisions for technical, financial support and provide incentives to industries using environment-friendly and energy-efficient technologies. • No royalty or tax for self-dependent industries on electricity and provision to sell excess energy to the national grid • Ordinance for auditing and reporting of energy intensity of industries • Provision to build the capacity of the Department to monitor and control pollution.
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

Key Plans, Policies, programs	Features
Motor Vehicle and Transport Management Act (1993)	• Legal provision for vehicles to pass the roadworthiness test for registration and operation - the test includes pollution test and age of vehicles. • Provision of penalties for violating the regulations and the spot check and fine for vehicles that are not roadworthy • Clear roles and responsibilities, and institutional setup of Department and Transport Management Committee • Appointment of transport inspector.
Forest Act (1993)	• Provision to hand over any part of National Forest to a user's group in the form of a community forest for developing, managing, and utilization of the forest.

The GoN has taken back the Electricity Bill -2077 recently, which was under consideration at the National Assembly[4]. The government is in the process of revising the law to allow the private sector in the power trade through an amendment to the Electricity Act[5]. There is huge pressure from the private hydropower developers as there is surplus power during the rainy season for allowing private sector involvement in open access through power trade inside the country and across the border. Currently, Electricity Bill 2080 is under consideration in the parliament.

1.7 Energy Pathway

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

[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

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.**

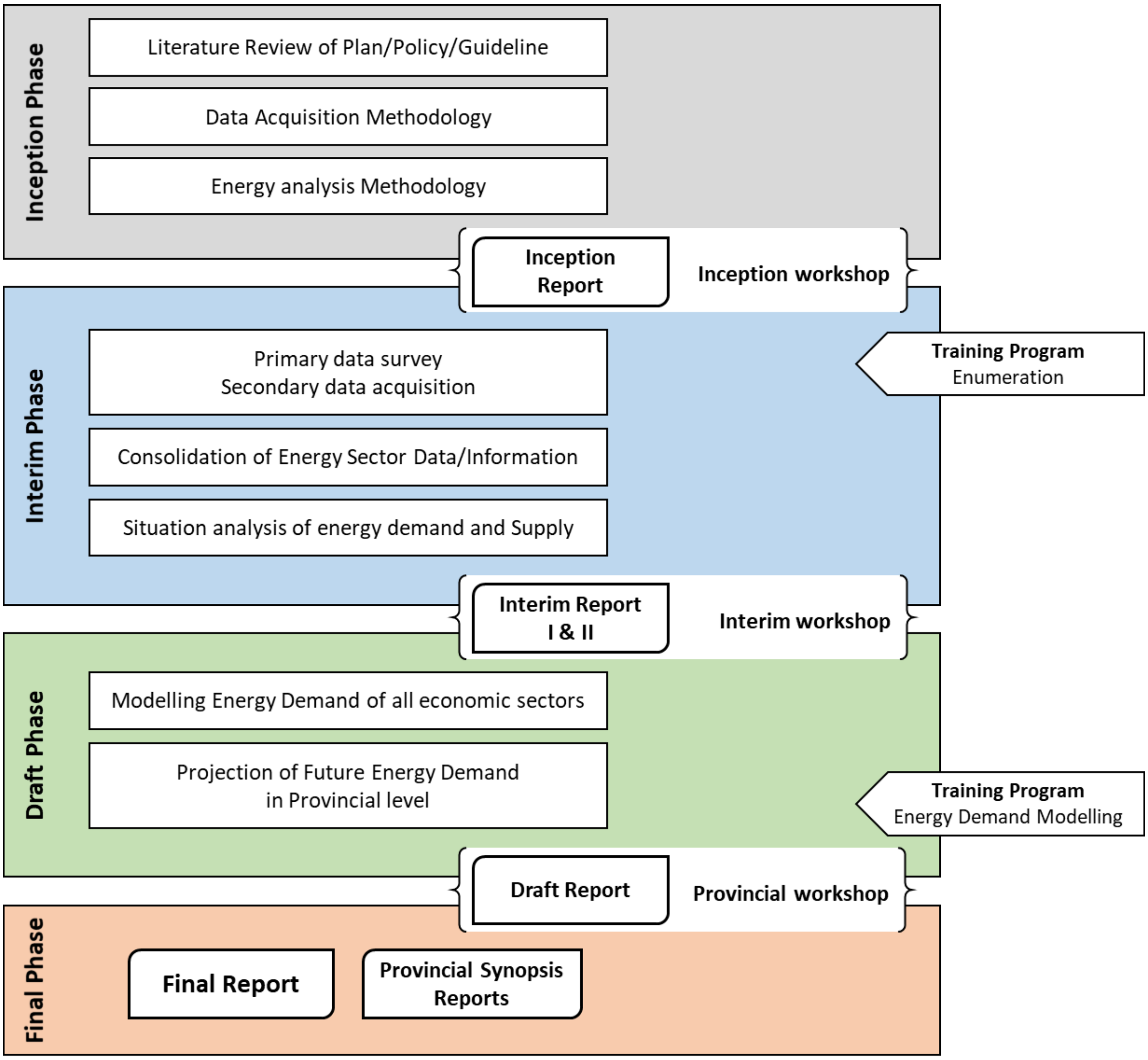


Figure 2-1. Methodological Framework

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

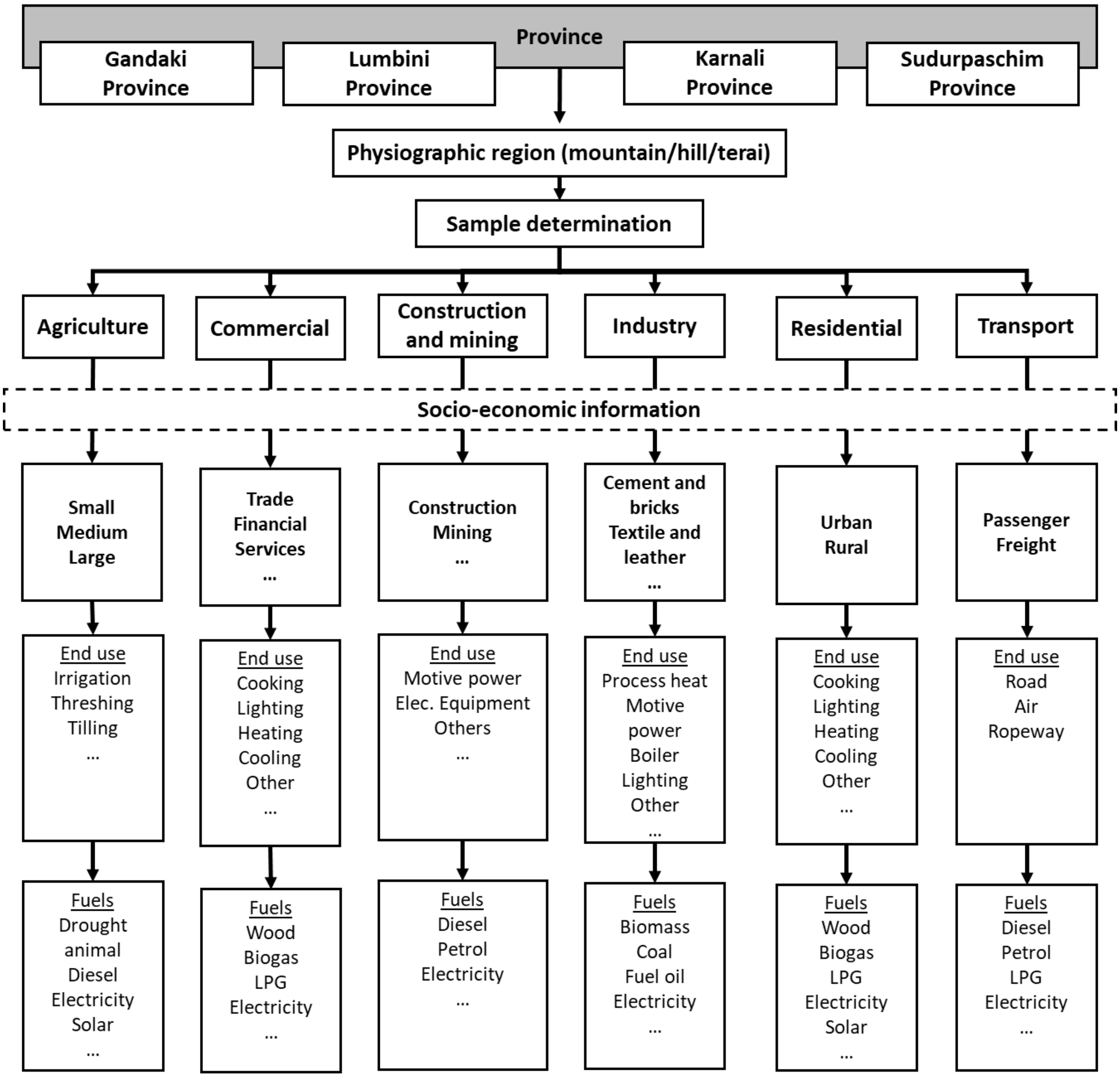
BOX 1: ENERGY SECTOR AND RESOURCES
State of Current Energy Demand and Changes Over Time by Sectors of Energy Uses: *a.* Residential (Household) Sector *b.* Industrial/Production Sector *c.* Commercial/ Service Sector *d.* Agricultural sector *e.* Transport Sector *f.* Construction and Mining Sector Supply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



2.1 Data Collection Methodology

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

Table 2-1. District Wise Population and Household Status

	Household	Rural Population	Urban Population	Total Population
Mountain				
Manang	1,545	4,925	-	4,925
Mustang	3,751	14,596	-	14,596
Hills				
Baglung	65,334	105,868	143,096	248,964
Gorkha	72,800	160,490	90,559	251,049
Kaski	163,476	75,589	518,452	594,041
Lamjung	44,873	24,197	129,283	153,480
Myagdi	29,201	72,305	33,062	105,367
Parbat	37,601	72,852	59,500	132,352
Syangja	70,710	84,737	169,540	254,277
Tanahun	93,168	113,937	213,025	326,962
Terai				
Nawalpur	95,351	91,997	288,861	380,858
Total	**677,810**	**821,493**	**1,645,378**	**2,466,871**

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

Data collection methodology of six sectorswas adopted as follows.

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

Sector	Total Samples	Response rate
Agriculture	4,007	99%
Commercial	3,847	104%
Industrial	256	101%
Residential	4,284	105%
Transport	745	99%
Construction and Mining	130	106%

- **Residential Sector:**

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

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

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

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

The general formula for the approximation of energy in the residential sector is

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

Equation 2

Where,

$E_{d,s}$	=	energy 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, 33% threshold was used for the determination of sample size and population size more than 750, then the estimation of the sample size shall be determined with 95% level of confidence, 5% margin error and at 5% non-response rate.

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

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

Equation 3

Where,

$E_{d,s}$ = energy 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 surveya vehicle is considered as the primary sample unit in this sector. The sample units are motorcycle, jeep, car, bus, truck, airplane, helicopter/train, boat, cable car etc. All transport sectorsare broadly divided into Road Transport (Passenger and Freight), Air transport and Ropeway, Navigation and Railways sub sector. Road, Air and Ropeway transport which is further be divided into public, private, corporate and government transport and others.The transport sector is classified as Transport sector 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, goods carrier services. In this sector buses, cars, jeeps, vans, motorcycles, and cable cars are used for passenger services and trucks, lorry, pickup could be the load carrier services. Similar categories can be made in the air transport sector.

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

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

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

Equation 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 sample calculation of commercial sector has been taken from National Economic Census 2018 by Central Bureau of Statistics. The database, however, takes account of the institutions that are not registered as well, which can affect the approximation as their output and value-added are not accounted for.

Since energy consumption patterns vary by commercial sector wise. The NSIC also classifies the commercial sector into different groups by the type of goods or service provided. To make representative all sectors during the survey, the commercial sector is classified as **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 was identified from the government registration office. Thesenumbers are considered as the populations for the 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 are collected with the information of what energy is used for what purpose. Such energy us summed up to get the total energy at each upper level – from per value added to per sub-sector to sector to 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 agriculture sector, land holding as defined by CBS has been taken. The land holdings are separated into three groups as per National Sample Census of Agriculture 2011/12The general criteria given by document and the categorization adoptedare 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 are collected with the information of what energy is used for what purpose. Such energy is summed up to get the total energy at each upper level – from per value added to per sub-sector to sector to 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. 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 has been collected using semi-structured questionnaires. The questionnaires and checklists prepared in English have been finalized after approval from WECS. Their suggestions have duly been incorporated. Thereby, the questionnaires and checklists have been translated into Nepali to ease the task for enumerators and respondents. The finalized tools have been pre-tested at the project sites district. Having received feedback on pre-testing, adjustments have been made to the tools before field mobilization.

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

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

2.2.3 Data Analysis

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

2.2.4 Workflow of Data Collection

The workflow of data collection is as shown in **Figure 2-2**. The template was designed at first. The final questionnairewas uploaded to the cloud server. Enumeratorsdownloaded the template using the server. The surveywas 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.

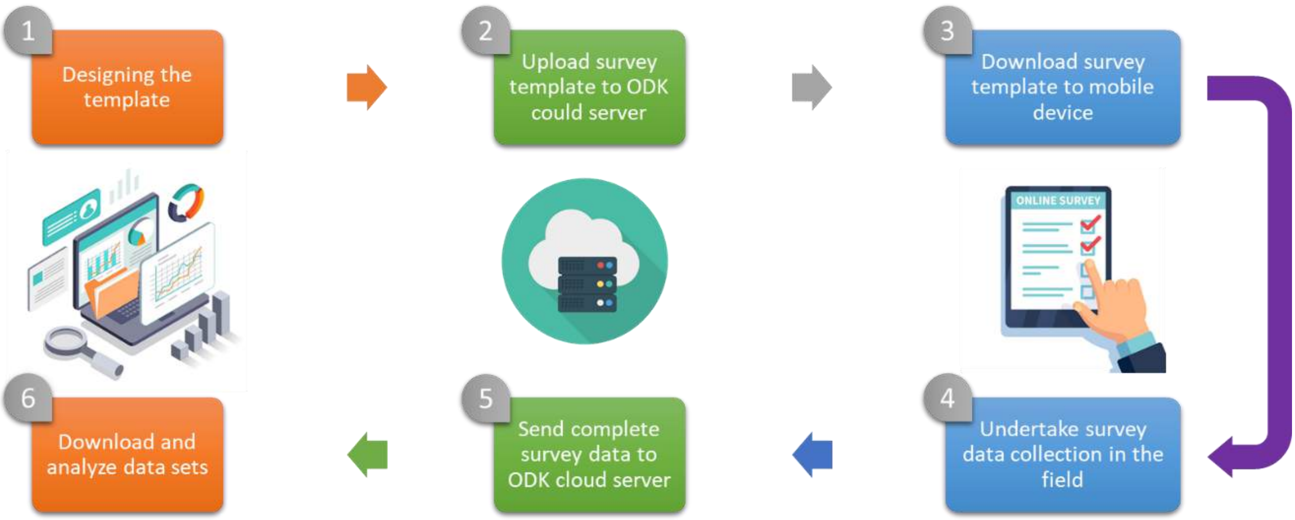


Figure 2-2. Workflow of Survey Design and Data Collection

3. Macroeconomic Analysis

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

3.1 Economic Status

The pandemic COVID-19 left unexpected severe adverse effects on the economy at both the national and the provincial levels in FY 2019/20 andin its succeeding fiscal years - FY 2020/21 and FY 2021/22, but at a decreasing trend. The annual GDP growth rate of the country in FY 2019/20 was reduced to -2.37%. In the same fiscal year, the annual GDP growth rate of Gandaki Provincefell to -0.71%. The annual GDP growth rate of the country in 2020/21 and 2021/22 were both positive and were 4.25% and 5.84% respectively. Similarly, those of Gandaki Province were also positive and at the increasing trend, i.e., 3.73% and 6.17% respectively in these two consecutive years, 2020/21 and 2021/22.

This decreasing adverse effect of COVID-19 on economic activities of both levels in FY 2021/22 had assisted to increase the economic growth rates of all provinces relatively compared to last FY 2020/21.

Figure 3-1 depicts that in the fiscal year 2021/22 the estimated GDP at consumers' prices was provisioned to Rs. 4,851,625 million, out of which, Gandaki Province had contributed Rs. 431,802 million (8.9%) to the national GDP. As the pandemic COVID -19 has been minimum, the estimated economic growth rate was expected to be 5.84% in the country whereas; the estimated annual growth rate of Gandaki Province was provisioned to 6.17% in the same fiscal year, while considering GDP at consumers' prices.

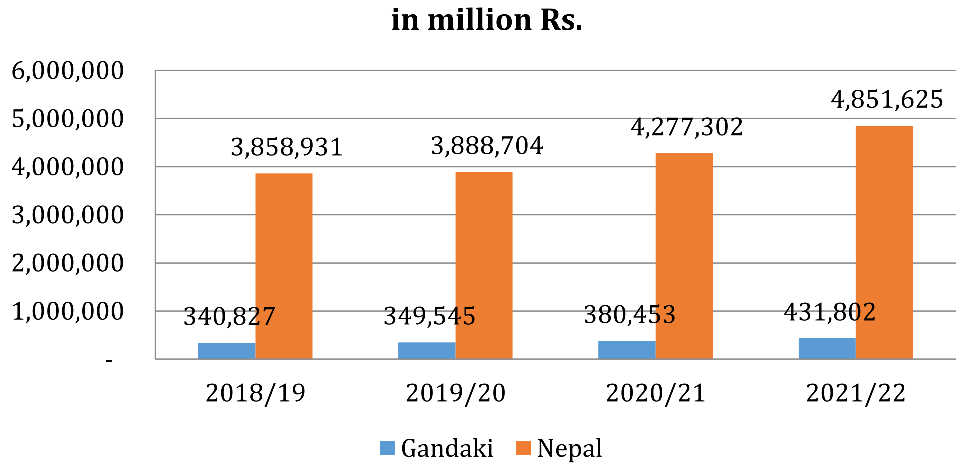


Figure 3-1. GDP at Consumers' Prices of Gandaki Province and Nepal (in million NPR)

In FY 2019/20, except annual growth rate of agricultural GDP (2.2%), those of both secondary GDP (-0.4%) and Tertiary GDP (-3.9%) were negative in Gandaki Province while considering GDP at basic prices. In this province, the annual growth rate of secondary GDP rapidly increased to 3.4% in 2020/21 and 11.3% in 2021/22 compared to other sectoral GDPs. Agricultural GDP was just mildly increased and could not resume at the previous growth rate level. The adverse effect of covid-19 on this sector does exist till now. Similarly, the situation does exist in the tertiary sector too, but its growth rate was relatively slightly higher than that of agriculture in succeeding post-covid-19 years (**Figure 3-2**).

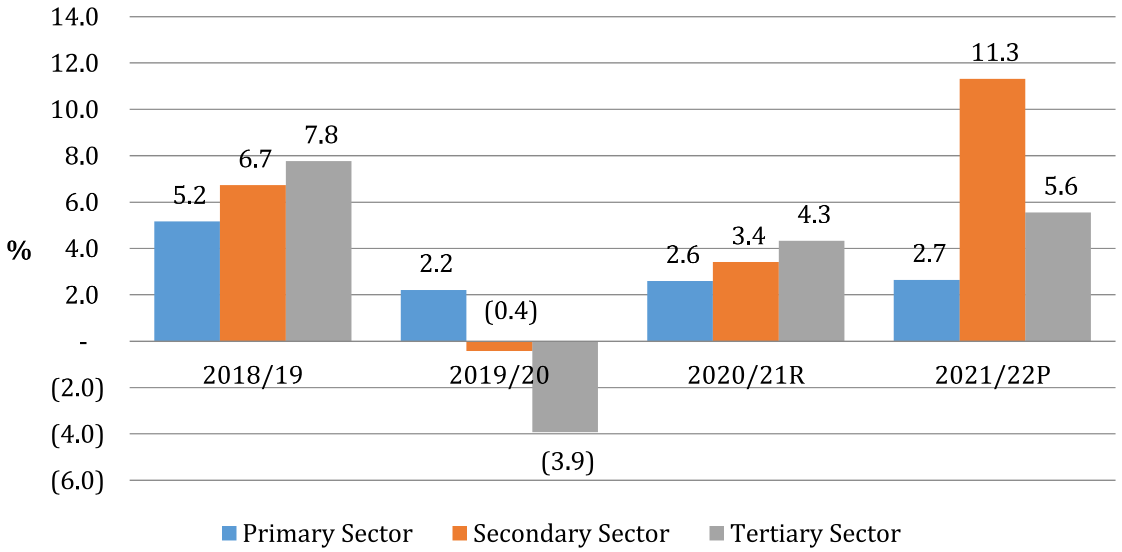


Figure 3-2. Annual Broad Sectoral Growth Rates in Gandaki ProvinceDuring (2018/19-2021/22)

Figure 3-3 shows that the major contributing sector to provincial GDP was the tertiary sector having around 55.6% share; whereas primary and secondary sectors contributed around 26.8% and 17.6% respectively in 2021/22 and the composition remained thesame in previous FYs too. The tertiary sector has gradually replacedthe primary and secondary sectors. The share of the secondary sector has been mildly declining despite having a rapid rise in its annual GDP growth rate.

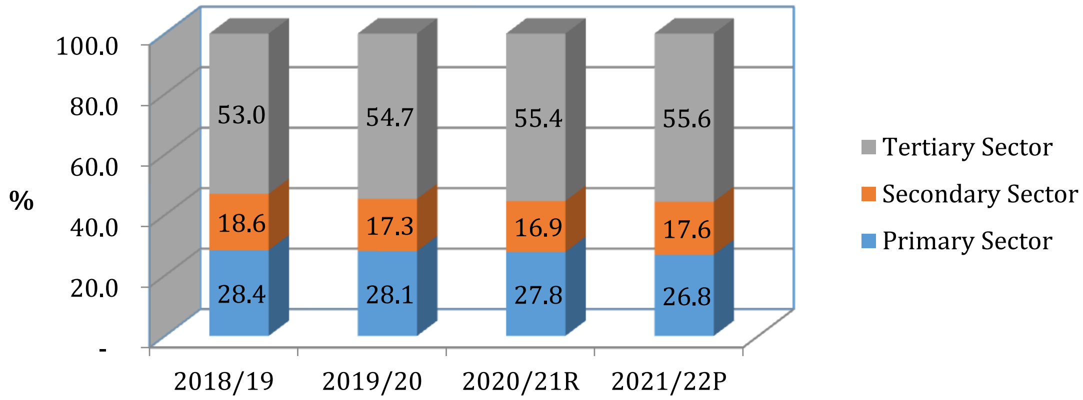


Figure 3-3. Composition of GDP at Basic Prices in Gandaki Province

The contribution of Gandaki Province to the national GDP at current basic prices is found around 8.9% (**Figure 3-4**). The primary sector contributes around 9.7%, the secondary sector 11.4%, and the tertiary sector 8.0% to their respective national sectoral GDP. Contributions of both provincial and all sectors are almost stable, and no remarkable changes are found.

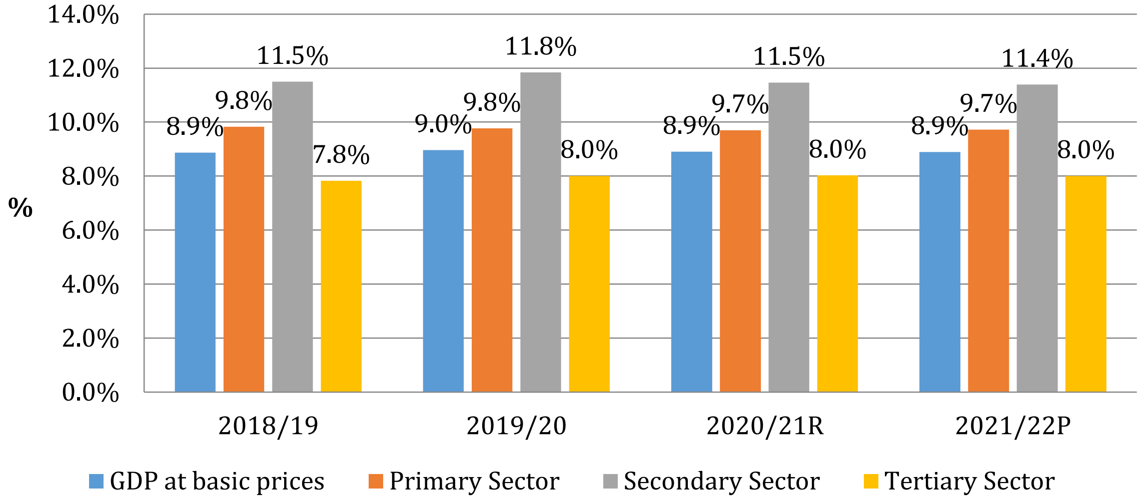


Figure 3-4. Contribution of Gandaki Province to National GDP at Current Basic Prices by Sector

(R-Revised, P-Preliminary)

Per capita income in Gandaki Province was estimated higher (US$ 1,437) than the national per capita income (US$ 1,372) in FY 2021/22.

3.2 Public Finance

Revenue and expenditure of Gandaki Province as percentage of its provincial GDP ware 2.56% and 6.73% respectively in FY 2020/21, which were lesser than those of the country, i.e., 2.7% and 7.63% respectively.

Table 3-1shows that both the national and the provincial total expenditures increased at a faster rate. The total expenditure of Gandaki Province was Rs. 13,928 million in FY 2018/19 and increased to Rs. 25,623 million, nearly double in two years. The weight or provincial share of national total expenditure was also increasing from 12.4% in FY 2018/19 to 13.6% in 2020/21. The ratio of capital expenditure in GandakiProvince was higher compared to the national ratio of capital expenditure and it was increasing at both the provincial and the national levels.

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

FY	Total expenditure in Rs. Million	Weight	Ratio of capital expenses (%)	National total expenditure in Rs. Million	Ratio of capital expenses (%)
2018/19	13,928	0.124	62.6	112,090	54.42
2019/20	20,414	0.131	68.5	156,114	57.21
2020/21	25,623	0.136	68.7	188,829	59.34

Source: Financial Comptroller General, 2022

The total expenditure of the government of Gandaki Province was Rs. 25,623 million (i.e., 13.6% of national total expenditure) in FY 2020/21 (**Table 3-2**). The total receipt of the province was Rs. 29,961 million (11.3% of national total receipts) in the same year. 85.5% of the total receipt was utilized as total expenditure but revenue contributed only 32.5% to the total receipt. Total expenditure was covered only 38.0% by revenue in this province. Grants contributed 46.6% to the total receipt. Thus, the major source of total receipt was granted in the country.

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

Description	Gandaki (In Rs.Million)	Nepal (In Rs. Million)	Share of Gandaki (%)	Utilization of funds (%)	
				Gandaki	Nepal
Provincial expenditure	25,623	188,829	13.57	85.5	71.2
Revenue	9,733	87,944	11.07	32.5	33.2
Tax	8,420	77,009	10.93	28.1	29.0
Others	1,313	10,936	12.01	4.4	4.1
Other receipts including irregularities	6,259	66,410	9.42	20.9	25.0
Grants	13,969	110,348	12.66	46.6	41.6
Repayment of loan and investment	-	541	-	-	0.2
Total receipt	29,961	265,243	11.30	100.0	100.0
Provincial reserved funds (surplus +/loss-)	(433.7)	(76,415)			

Source: Financial Comptroller General, 2022

Table 3-3 shows that the provincial government of Gandaki Province spent Rs. 7,769 million, out of which 44.7% as recurrent expenditure and 55.3% as capital expenditure in FY 2021/22.

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

		in Rs. Million
Description	Gandaki	Nepal
Recurrent expenditure	3,471	35,449
Capital expenditure	4,298	28,591
Financing	-	1,000
Total expenditure	7,769	65,041
Expenditure weight	11.9%	100.0%

Source: Financial Comptroller General, 2022

The total number of branches of banks and financial institutions in Gandaki Province in 2021/22 (till 2078 Falgun) was 1,405, which was 12.4% of the national total branches, 11,349, and persons per branch was 1,765 in the same year. Thus, financial access in Gandaki Province was relatively better compared to that in the nation (2,572 persons per branch) (**Table 3-4**).

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

Province	Gandaki	Nepal
Commercial Bank	593	4,930
Development bank	186	1,086
Financial companies	35	257
Micro finance	591	5,076
Total	1,405	11,349
Share (%)	12.4	100.0
Population** (persons /branch)	1,765	2,572

Source: Nepal Rastra Bank, 2022

3.3 Macroeconomic Modelling

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

3.4 Economic Growth

The economy has been classified into three major sectors namely agriculture, industry, and services. After the restoration of democracy in 1990 in the country, liberalized economic policy under the globalization was followed and private sector was encouraged to involve in economic activities reducing the government involvements. Privatization policy was followed to privatize the public enterprises. Consequently, economic activities were expanded and thus, a relatively higher economic growth rate was achieved till the start of domestic 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 Maoist problem and political instability in the country. Maoist conflict and political instability was prolonged till the peace treaty between the government and Maoist Party in 2005/06. Both industry and services sectors were badly influenced by the strikes, Nepal general strike and political conflicts caused by political turmoil and political instability during these decades. Many industries and organizations were forced to shut up their operations. Load shedding was another major cause of slowing down the economic activities in the country. Another serious problem is the massive out-flow of Nepalese youths for overseas employment since the startof domestic political conflict and turmoilin 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 comingtwenty-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 **Table 3-5**and **Table 3-6**.

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, 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	40.7	(4.0)	2.5	1.7	1.7
ATCA1	(0.9)	0.6	0.4	0.3	0.4
CDIAG1	3.0	2.8	2.1	1.8	2.1
CDIIND1	12.2	9.4	9.5	9.4	9.5
CDISERV1	7.2	6.7	6.9	7.0	6.9

In the above table, trend projections of average annual percentage growth rate of cumulative gross fixed capital formation in agriculture and industry sectors are at declining trend whereas that in services sector has a mild rising trend. The use of chemical fertilizers is usually based on its availability not on demand as its supplying public corporations such as: Agriculture Inputs Corporation and Salt Trading Corporation could not meet the farmers' demand in time. The projected average annual growth rate of ATC1 has also been gradually declining as the tendency of Nepalese youths including agriculture labourers for foreign employment is increasing.

Other Exogenous Variables:

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

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

In Percent

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

- **Reference Scenario**

It is assumed that the country's economic situation will gradually be improved in future. The government has concentrated on the economic prosperity of the country. The government has decided to develop the agriculture sector encouraging and mobilizing the returnees from overseas employment by providing them economic incentives and skill training to be self-employed in agriculture sector. Some of them have returned with skills and technical know-how too. They have invested and operate their agriculture farms. The load shedding problem has also been almost completely solved. The NEA has started to replace other types of energies with electricity by linking the electricity of completed hydroelectricity projects to national grids. That's why; investments on agriculture (vegetables farming, livestock, horticulture, poultry and fish farming and agro - processing industries), industry (electricity, mining, manufacturing and construction) and tertiary or service sectors (wholesale and retail trade, hotels and restaurants, transport, storage and communications, financial intermediation, real estate, renting and business activities, public administration and defense, education, health and social works, and other community, social and personal services) are expected to go up and will increase the productions as well as will generate employment opportunities to solve the rising national unemployment problem.

In order to reduce the faster increasing foreign trade deficit, the government is trying to implement the export promotion and import substitution policies for increasing exports of goods and services on the one hand and on the other hand for gradual reduction of the imports. For both purposes, major way outs are the increases in outputs of agriculture and industries. The present government has recently signed in the Nepal- India power exporting agreement of 10,000MW electricity to India in 10 years (EoI, 2024). The expanding economic activities will also demand production and productivity of services sector too in consistent way. Investment has to be increased for higher growth to achieve the abovementioned goals. Sustainable development goals have 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	40.7	(1.0)	3.8	4.6	4.3
ATCA1_1	(0.9)	0.7	0.7	0.8	0.7
CDIAG1_1	3.0	3.8	4.9	5.8	4.9
CDIIND1_1	12.2	9.6	10.8	11.8	10.8
CDISERV1_1	7.2	6.7	7.5	8.5	7.7

- **High Growth Scenario**

It is assumed in the High growth scenario that all policy /exogenous variables namely, CDIAG1, CDIIND1, and CDISERV1 are exogenously projected with further higher increment in order to achieve higher growth rates of sectoral as well as national GDP growth rates. The agriculture sector has increased slightly only as the productivity of capital in this sector is relatively low whereas, that of services sector is relatively moderate and high in industry sector. That’s why; CDIIND1 and CDISERV1 have increased higher rate for higher GDP growth. The country has achieved political stability after facing a longer period of economic recession due to nearly two decades long political turmoil and political transition. The country has also faced serious economic hardships for nearly two years due to the worldwide outbreak of the COVID-19 pandemic at the end of the year 2019. So, in order to revive the economy faster, the country will need a higher economic growth to compensate the economic losses to resume its normal growth in future. That’s why; it is targeted to have 7.1 and 8.0 percent average annual growth rate of GDP at producers’ prices for coming 28 years in medium and high GDP growth scenarios and accordingly, average annual growth rates of these policy/exogenous variables ACMFERT1, ATCA1, CDIAG1, CDIIND1, and CDISERV1 have been projected at the higher side in order to achieve the targeted growth rate. Other exogenous variables have been projected using the trend method as in Low Growth Scenario. The projected average annual growth rates of these policy/exogenous variables are presented in the table below.

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

In percent

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

3.7 Projection of Provincial Gross Value Added by Industrial Division

The 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%

(From Economic projection calculations)

Three scenarios of provincial gross values added by industrial division for each concerned province have been forecasted based on 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 circumstances. Scenarios provide a framework for exploring future perspectives, including various combinations of activities, technology options and their implications. Scenarios are useful tools for investigating alternative future developments and their implications, for learning about the behavior of complex systems such as energy and environment systems and for policy-making decisions related to them(Nakicenovic, 2000).

4.2 Major Assumptions/Options for Demand(Supply) Analysis

4.2.1 Economy and Population Growth

The scenario development process requires certain drivers for activities. The rate of activities is dependent on specific variables. In the study, the activities are linked with economic and demographic parameters. The agricultural, commercial, and industrial activities are assumed to be dependent on respective gross value added (GVA) in each sector respectively. Meanwhile, in the residential sector, waste outputs are assumed to be dependent on population. The transport sector, on the other hand is dependent of both economic and demographic parameters for freight and passenger transportation respectively. Thus, the scenario development is based on provincial and sectoral GVA, and population growth rates as shown in **Table 4-1.** The GDP growth rate is one of the uncertain parameters which can be affected by many factors such as national development activities, political influence, international trade as well as even natural calamities. Thus, GDP growth rates are taken from the targets set for national economy in government documents or were calculated based on the macro-economic activities in the provinces as detailed in Chapter 3. The population growth rate for each province has been taken from census data by Central Bureau of Statistics (CBS, 2012; Worldbank, 2013; CBS, 2014). Another major assumption undertaken in the model is that the economic activities go hand in hand with GDP growth to reach the target set, thus indicating growing sectoral GDP or GVA also require increase in activity such as production in respective sector and vice versa.

Table 4-1. Assumptions and Sectoral Categorization

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

*Details are given in Chapter 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 purposes. The major drivers of energy sectors are assumed to be dependent on economic and demographic parameters. **Table 4-2** shows the 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 in 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[6], and a short term, medium term, and long-term targets have been devised. The initial data collected from the survey have been used to develop a base year energy model with inclusion of socio-economic parameters. Based on predicted demographic and economic parameters, the energy scenarios have been developed at the provincial level that include –

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

The energy scenario development has been a two-step process. Firstly, MAED is for energy demand projection as it is one of the robust, freely available energy demand analysis softwares. Secondly, TIMES model is used as the MAED is limited or demand projection only, while the TIMES model is capable of analyzing the supply side as well as the emissions of the energy system. Although the details of data required in TIMES is much vast, as MAED provides a rigid framework, the data required for both models can be derived from same sets of information derived from primary survey and secondary sources as depicted in **Figure 4-1.** The results in both the energy models are compared, calibrated, and verified for validation of input sets of economic and demographic data and their respective outputs.

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

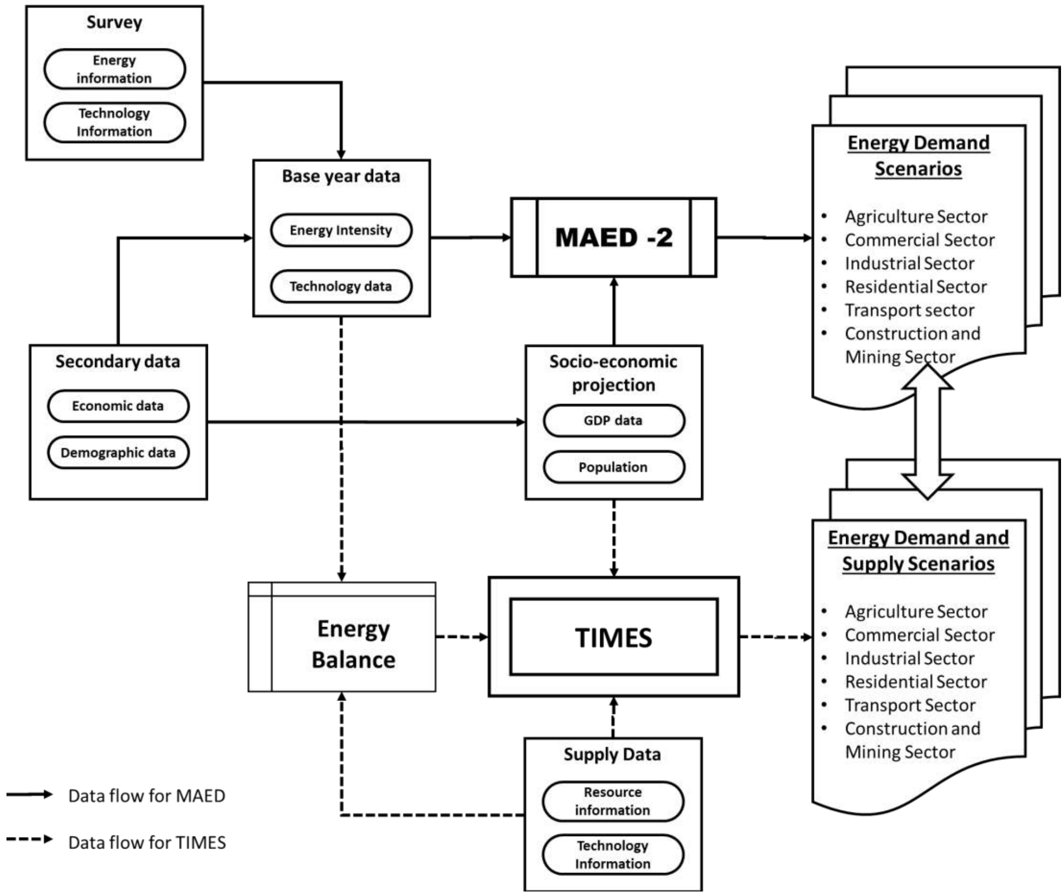


Figure 4-1. Methodological Framework of Projection in MAED and TIMES

4.3.1 Choice of the Modelling Tool

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

Amongst the energy models presented above, TIMES model is the advanced successor of MARKAL – one of the most widely accepted and robust energy models. Nevertheless, other energy modeling tools given are also particularly good ones. International Energy Agency – Energy Technology Systems Analysis (IEA-ETSAP), the developer of the MARKAL model, has now advanced the state-of-the-art in energy system modelling with TIMES (The Integrated MARKAL-EFOM System), the evolutionary successor to MARKAL. The ETSAP executive committee has decided to promote TIMES for new users since 2008. The trend in energy modeling tools shows that TIMES is the most widely used least-cost energy system optimization model for dynamic energy planning and policy development, both in the developed and in the developing countries. The model will facilitate harmonization and coordination of policy formulation at the provincial and central level to facilitate better communication among policy makers with the goal of fostering sustainable energy development and energy security in the country.

The TIMES model has been used for developing least-cost optimization scenarios. However, the energy demand projections were carried on the MAED framework. The results and scenarios developed using such amodeling framework will have much more valid acceptance from the development partners and multilateral financial institutionsas these modeling frameworks are widely used in other developed and developing countries.

4.4 Energy Demand Projection

The energy demand is calculated by the model MAED_D as a function of a scenario of possible development. This scenario covers two types of scenario elements (**Figure 4-2)**.

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

4.4.1 Model for Analysis of Energy Demand (MAED)

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

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

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

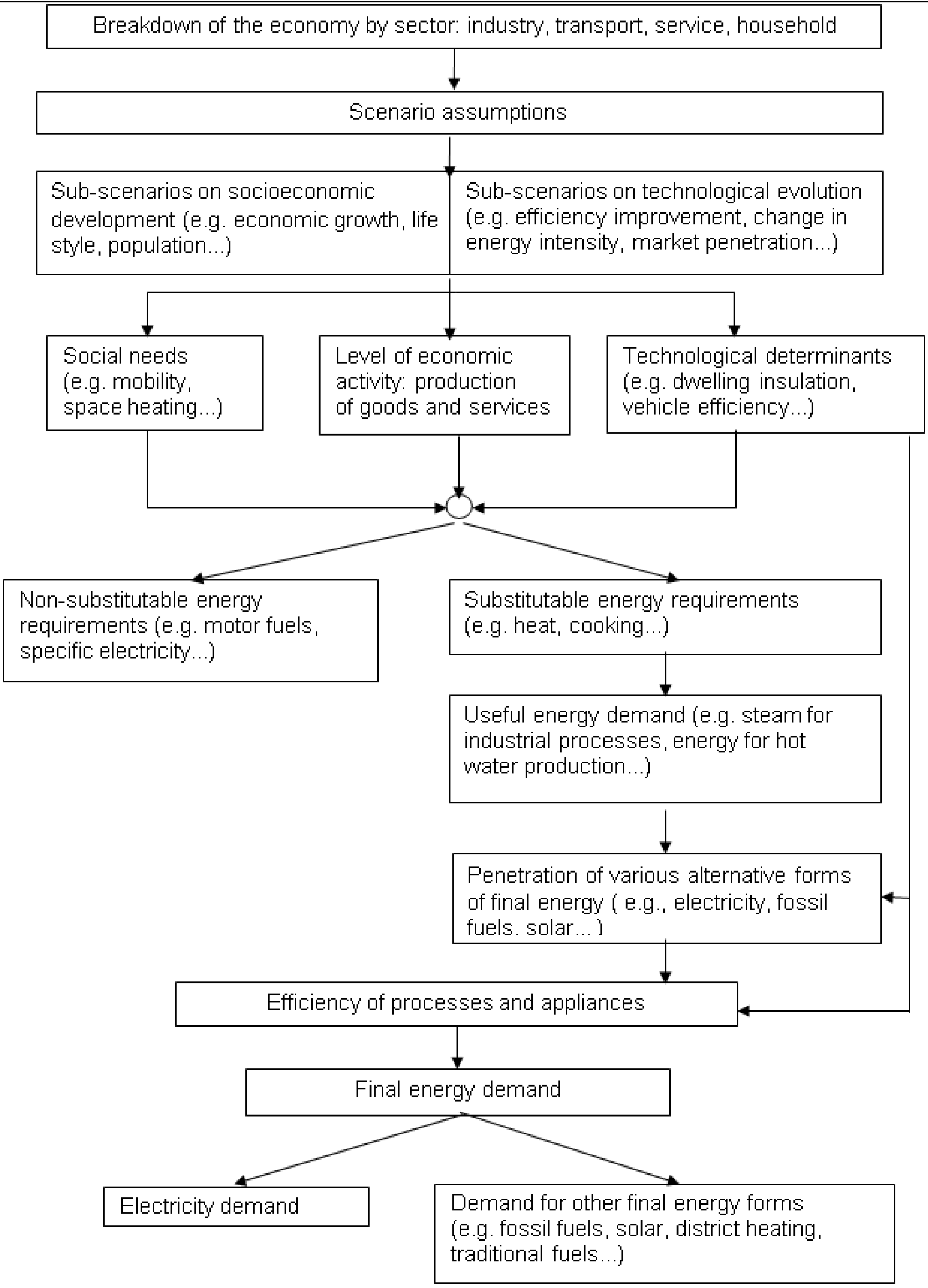


Figure 4-2. Scheme used to Project Useful and Final Energy Demand in Module 1 of MAED

4.5 Energy Supply Analysis

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

4.5.1 The Integrated MARKAL-EFOM System (TIMES)

The TIMES model generator was developed as part of the IEA-ETSAP (International Energy Agency - Energy Technology Systems Analysis Program) to conduct energy and environmental analyses. It is the successor of MARKAL. The model combines two different, but complementary, systematic approaches to modeling energy: a technical engineering approach and an economic approach. TIMES is a technology rich, bottom-up model generator, which uses linear-programming to produce a least-cost energy system, optimized according to several user constraints, over medium to long-term time horizons.

TIMES models include all the points of energy flow from primary resources to end-use consumers, including the processes of transformation, transportation, distribution, and conversion of energy into the supply of energy services. On the energy supply-side (producers), it comprises fuel mining, primary and secondary production, and exogenous import and export. Through various energy carriers, energy is delivered to the demand-side (consumers), which is structured into sectors. The mathematical, economic, and engineering relationships between these energy "producers" and "consumers" are the basis of underpinning TIMES models. Once all the inputs, constraints and scenarios have been put in place, the model will attempt to solve and determine the energy system that meets the energy service demands over the entire time horizon at the least cost. The results will be the optimal mix of technologies and fuels at each period, together with the associated emissions to meet the demand **Figure 4-3.**

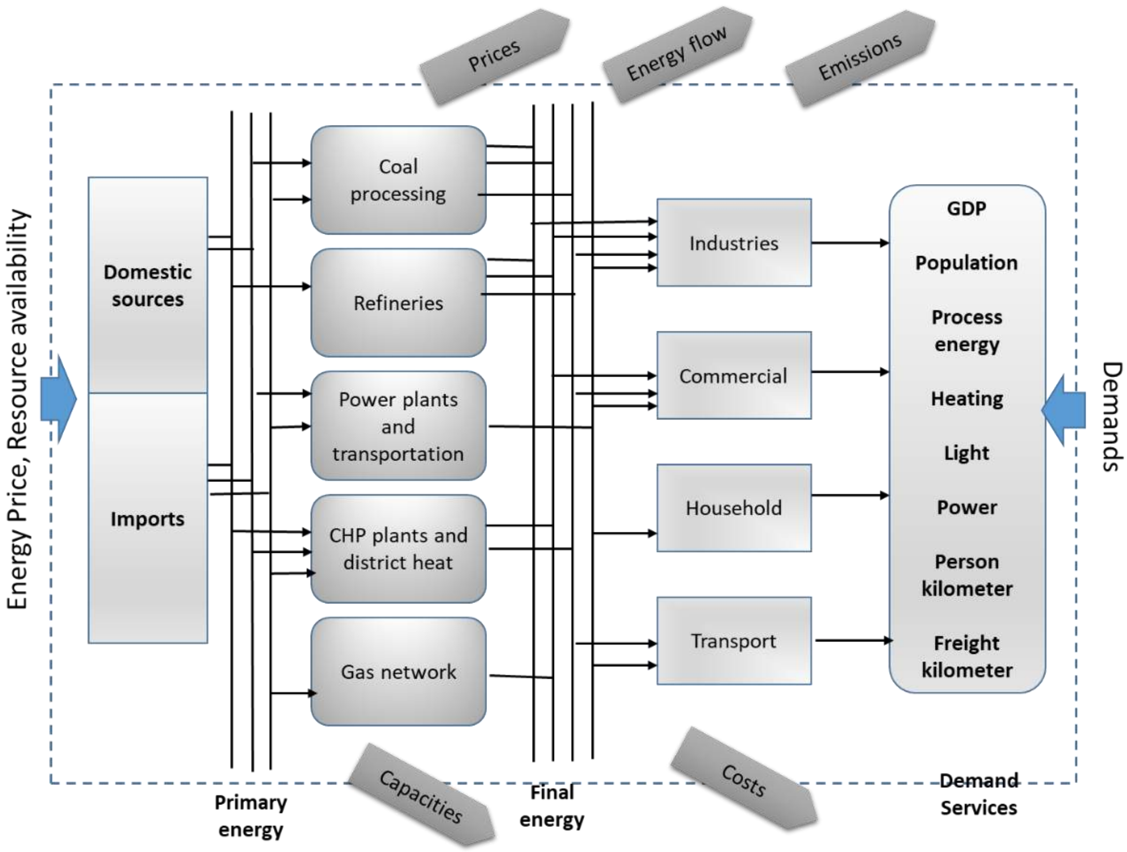


Figure 4-3. Structure of TIMES Framework

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

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

- *Process technologies* convert one energy carrier into another, excluding load-dependent ones such as electricity.
- *Conversion technologies* convert an energy carrier into electricity and/or district-heat.
- *Demand technologies* consume an energy carrier to meet end-use demands.
- *Emissions* encompass the environmental impacts of the energy system.

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

TIMES Model Run and Solutions

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

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

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

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

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

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

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

s.t. $\sum_{k} CAP_{k,i}(t) \geq DM_i(t)$ i = 1,2, …., I; t = 1,2,…, T

and, $B.X \geq b$

Equation 4.1

Where, X = vector of all decision variables

I = number of demand categories

CAP = capacities of end-use technologies

DM = exogenous demands to be satisfied

B = coefficient of other constraints

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

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

5. Energy Supply Situation

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

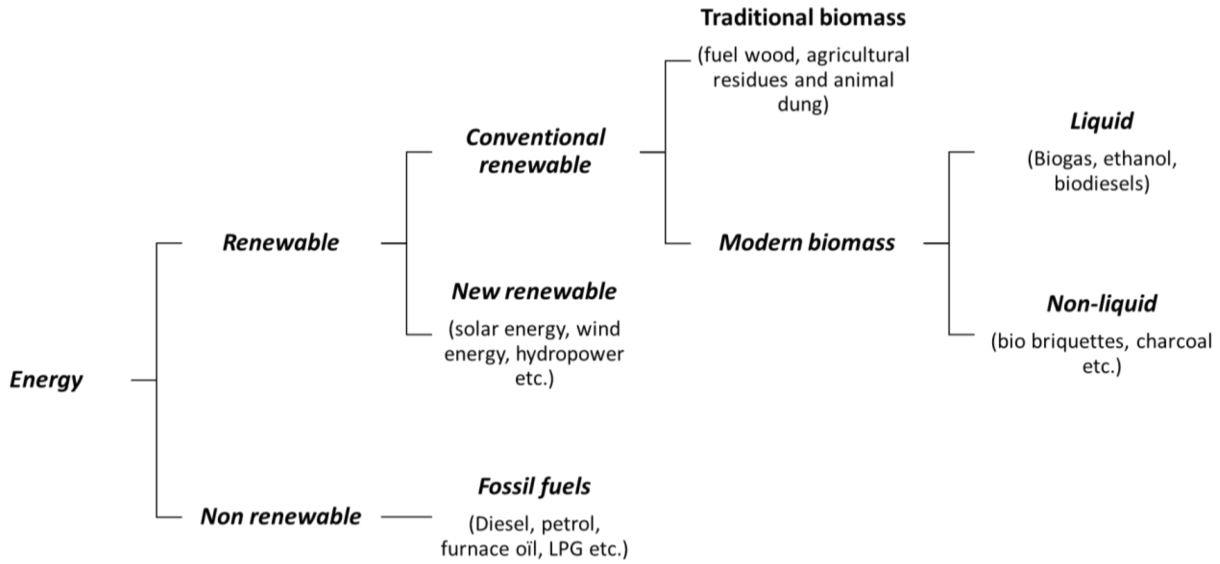


Figure 5-1. Energy Classification for Nepal[7]

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

5.1 Solid Biomass

Gandaki Province of Nepal is blessed by nature with lots of forests in terai, valleys like Pokhara, mid-hills, and high hills. This province has 0.178 hectare as average forest area per person. When considered average value of forests as average stumpage value of grade A and B chirpine, total value of forests in the province is NRs 1.1 billion. In addition, there is good sunlight, enough water in the watersheds of Gandaki and its tributaries of the province, and alluvial soils. Although deforested to some level, there are still very good forests in the province. But urbanization and agriculture have impacted good forests, and some good forests are changed into non-forests, especially in the Nawalpur district. Similarly, human pressure for fuelwood in the past had changed the forests into degraded

[7] As per Terms of Reference

ones. But, due to the better conditions for plant growth and past interventions of community forestry, Gandaki Province still has good potential for forest management and production. Therefore, from perspective of energy these forests have very high potential. On the other hand, due to easy accessibility of forests, most of the rural people in the province still depend upon bioenergy as cheap source of energy, which is very important for them.

5.1.1 Forest in Gandaki Province

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

Subtropical broad-leaved forests occur mainly between 1,000 meters and 2,000 meters above sea level and are dominated by *Schimawallichii* and *Castanopsisindica*. Riverine forests of *Cedrelatoona* are common along river valley sides, while *Alnusnepalensis* is widespread along streams and exposed sites and moist places. Subtropical conifer forests primarily consist of *Pinusroxburghii* forests that occur in southern dry slopes between 1,000-2,000 meters.

Lower temperate broadleaved forests are generally confined between 1,700 meters and 2,500 meters. *Castanopsistribuloides, Castanopsishystrix* and *Quercuslamellosa* 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 andhimalayan 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 *Abiesspectabilis, Piceasmithiana, Betulautilis, and Rhododendron spp.* Alpine scrub vegetation occurs between the treeline (around 4,000 meters) and snowline (around 5,500 meters). **Table5-1**showsthe forest area and major species of Gandaki Province.

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

SN	physiographic zone	altitude (m)	districts	forest area (ha)	major species	stem Total Total Stem volume (m3)	Growth rate%
1	Terai	500	Nawalpur	76,493	sal, sisoo, khair, asna	11,496,898	medium
2	Middle mountain	500-3000	Gorkha, Lamjung, Tanahun, Kaski, Parbat, Syangja, Baglung	558,198	chima-castanopsis, pinus, oak, alnus	62,294,897	medium
3	Higher mountain	3000-5000	Manang and Mustang, Myagdi	160,236	rhododendron, abies, acer, betula, picea	32,447,790	slow

(DFO, 2075,2074,2073,2072,2071; DOF, 2071,2061)

Forest resources are very important for ecosystem balance and people's livelihood in Nepal, and it is true also for Gandaki 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 aiming 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, 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 Gandaki Province

DhorpatanHunting Reserve and Annapurna Conservation Area are protected areas in the province, which are managed for biodiversity conservation. All remaining forests are managed for production which includes timber, fuelwood, and non-timber forest products. The most prominent forest management in Gandaki Province is community forests, although there arelimited Collaborative Forest Management and block forest managed by the government in Nawalpur.

Area of forests in Gandaki Province under community forest management is given below. The table shows that 203,383 ha area is handed over to 3,684 forest user groups (DoF, 2019). This figure is low as compared to the community forests area handed over in other hill districts (**Table 5-2**).

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

SN	Districts	No of UG	Area Managed in Ha
1	Manang	19	6,738
2	Mustang	NA	NA
3	Gorkha	464	23,364
4	Lamjung	335	21,822
5	Tanahun	591	38,502
6	Kaski	489	17,904
7	Parbat	356	12,048
8	Syangja	512	15,474
9	Myagdi	310	24,206
10	Baglung	485	27,618
11	Nawalpur	123	15,707
	Total	**3,684**	**203,383**

(DFO, 2075,2074,2073,2072,2071; DOF, 2071,2061)

5.1.3 Wood as Fuel

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

5.1.4 Effect of Fuelwood Collection on Forest

In past decades, because of the increasing population, the area under agriculture expanded and forest shrunk. The forest area in the Terai is declined by 16,500 ha in the years from 2001 to 2010 and by 32,000 ha in the 19 years from 1991 to 2010.The 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 area (FRA/DFRS 2014). In Nawalpur district also, the land under cultivation increased at cost of forest land. On the other hand, due to poverty, the demand for fuelwood increased despite the rapid growth in the commercial energy sector. The fuelwood is practically free ifpeople can afford time for collection from forest as well as those swept by river as seen in lower terai belts. Large quantity of fuelwood is being collected from the community-managed and government-managed forest by the local people.

In the present context, forests, and forest conditions in different districts of Gandaki Provincearegiven in **Table 5-3.**

Table 5-3. Forest Area and Actual Fuelwood Produced as per Management Plans

Districts	Access Area in ha	Fuelwood produced in chatta
Manang	74,460	80
Mustang	25,580	
Gorkha	118,310	1,569
Lamjung	82,317	1,030
Tanahun	74,294	10.28
Kaski	85,316	226
Parbat	24,732	643
Syangja	42,948	744
Myagdi	93,354	5,604
Baglung	74,460	107
Nawalpur	68,844	
Total	**764,615**	**10,013.28**

Note: A chatta is length 20 ft, height 5 ft, width 5 ft
(DFO, 2075,2074,2073,2072,2071; DOF, 2071,2061).

5.1.5 National Demand and Supply Situation

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

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

- **Fuelwood from Community Based Forests**

Most of the forest products in Gandaki Province come either from community forests or government forests or private forests. Thegovernment forests are mostly over matured and degraded(Paudel et al 2021). Therefore, these forests have small growing stock. In the past, although forest management plans were made, forests are not managed on a sustained basis. Cutting down the trees in government forests is often limited to the clearing of sites for different projects like road, resettlement of villagers, transmission lines, irrigation channels, industrial states etc. Lately, management has been initiated in community forests and collaborative forests as pilot programs. The results of these forest management are highly positive, therefore, in the future managed forest area will be increased and this will produce more forest products like timber and fuelwood.

5.1.6 Potential Increment

If appropriately done, sustainable management of forests in Nepal could not only increase and stabilize the supply of forest products, but it would also help in contributing to the livelihood of the people involved in 19,919 community forests which mean 2,546,760households are involved in community forest management (DoF, 2019) 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 5-4** provides the fuelwood collection in the Gandaki Province.

Table 5-4. Forest Area and Potential Fuelwood Production

	Forest Area ha	Accessible forest area ha	Fuelwood Production/year in m3	Fuelwood Production/year in kilo ton
Manang	28,087	25,278	103,060	73.27
Mustang	28,422	25,580	104,289	74.15
Gorkha	131,456	118,310	265,829	189.0
Lamjung	91,463	82,317	184,955	131.5
Tanahun	82,549	74,294	166,930	118.7
Kaski	94,796	85,316	191,696	136.3
Parbat	27,480	24,732	55,570	39.51
Syangja	47,720	42,948	96,499	68.61
Myagdi	103,727	93,354	380,605	270.61
Baglung	82,734	74,460	167,304	118.95
Nawalpur	76,493	68,844	208,824	148.11
Total			**1,925,061**	**1,368.72**

(DFO, 2075,2074,2073,2072,2071; DOF, 2071,2061)

Thus, annual fuelwood from the whole Gandaki Province is 1,925,061 m^3 (This is harvestable quantity). This volume accounts for 11 categories, 10 defined species and 1 other (miscellaneous).And to classify timber production as per each species, proportion of stem volume of each species is multiplied to 1,925,061 m^3. Thus,the obtained value is converted to the kilogram and or tone using wood density (average 1 m3 =711 kg) and totaled to final fuelwood to 1,368,720 tons or 1,368.72 kilo tons.

5.2 Biogas in Gandaki Province

- **Livestock in the Gandaki Province**

The potential of biogas production is directly related to the availability of local feedstock in the area. In Nepal, animal dung is considered as the major feedstock for biogas production at 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 the greenhouse gas emission from methane (AgStar, 2011). Biogas being a clean fuel also helps in the control of air pollution resulting from burning 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 the collectable dung playa major role in determining the biogas production potential. The number of livestock in different districts of Gandaki Province is given in **Table5-5.**

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

District	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Baglung	22,490	87,708	9,531	126,668	10,981	389,249	1,826
Gorkha	68,047	63,568	18,726	273,362	12,644	592,781	444
Kaski	42,308	47,768	13,328	148,835	23,095	2,858,939	13,029
Lamjung	19,376	35,777	13,401	145,559	7,467	320,981	960
Manang	2,308	0	3,405	5,879	79	7,105	0
Mustang	6,851	126	5,258	55,797	32	10,153	116
Myagdi	33,516	26,646	28,840	108,660	2,577	211,005	2,750
Nawalpur	74,545	68,492	2,004	115,334	24,546	921,278	18,472
Parbat	16,143	28,137	2,618	55,970	7,516	297,284	4,652
Syangja	26,505	106,804	2,044	250,485	24,646	480,795	1,511
Tanahun	51,717	56,472	714	387,376	57,272	580,953	1,283
Total	**363,806**	**521,498**	**99,869**	**1,673,925**	**170,855**	**6,670,523**	**45,043**

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

For production of biogas, dung from cattle and buffaloes are considered collectable dung while other livestock are considered as not collectable because these animals are not put in shade but grazed in forests and other communal lands. Considering production of dung as 10 kg/day from cattle and 15 kg per day from buffalo (WECS, 2010), dung production for Gandaki Province can be estimated as shown in **Table5-6.**

Table 5-6. Dung Production in Gandaki Province

District	Cattle	Buffaloes	Dung produced from cattle tons/ year	Dung produced from buffalo tons/ year	Total dung production tons/Year
Baglung	22,490	87,708	82,089	480,201	562,290
Gorkha	68,047	63,568	248,372	348,035	596,406
Kaski	42,308	47,768	154,424	261,530	415,954
Lamjung	19,376	35,777	70,722	195,879	266,601
Manang	2,308	-	8,424	-	8,424
Mustang	6,851	126	25,006	690	25,696
Myagdi	33,516	26,646	122,333	145,887	268,220
Nawalpur	74,545	68,492	272,089	374,994	647,083
Parbat	16,143	28,137	58,922	154,050	212,972
Syangja	26,505	106,804	96,743	584,752	681,495
Tanahun	51,717	56,472	188,767	309,184	497,951
Total	**363,806**	**521,498**	**1,327,892**	**2,855,202**	**4,183,093**

5.2.1 Potential of Biogas Production Per Year

The estimation of potential biogas production in Gandaki Province is done considering biogas production factor as 0.036 cubic meter per kg of dung (WECS, 2010), its district-wise production potential in cubic meter for the year 2020/2021 is estimated as below. Per cubic meter of biogas is further converted into the energy using conversion factor of 1 cubic meter of dung equals to 20 MJ (Vaid, V. & Garg, S., 2013), **Table 5-7**shows the potential energy production from biogas.

Table 5-7. Potential of Biogas

District	Total dung production "000" tons/Year	Biogas in "000" cubic meter	Energy in "000" GJ per year	Potential%	Potential in 000 GJ
Baglung	562	20.242	404.85	0.75	303.64
Gorkha	596	21.471	429.41	0.75	322.06
Kaski	416	14.974	299.49	0.75	224.62
Lamjung	267	9.598	191.95	0.75	143.96
Manang	8	0.303	6.07	0.5	3.03
Mustang	26	0.925	18.50	0.5	9.25
Myagdi	268	9.656	193.12	0.75	144.84
Nawalpur	647	23.295	465.90	1	465.90
Parbat	213	7.667	153.34	0.75	115.00
Syangja	681	24.534	490.68	0.75	368.01
Tanahun	498	17.926	358.52	0.75	268.89
Total	**4,183**	**150.591**	**3,011.83**		**2,369.20**

Temperature plays a significant role in the production efficiency of biogas plants. At lower temperature, biogas production is low. The Terai is 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, Potential of biogas production is considered 50% for 2 high hill districts, 75% for 8 mid hill districts, and 100 % for the remaining 1 Terai district. As per **Table 5-7**, the production of biogas for Gandaki Province is 2,369 thousand GJ.

5.2.2 Waste-to-Energy Potential from Commercial and Municipal Waste in Gandaki 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 one of the promising alternatives for solid waste management since these intend to recover energy from the waste thereby reducing the quantity of waste to be sent for dumping at 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 minimize carbon emissions from incineration/ burning of waste.

Some of the promising sectors for W2E conversion are (i) 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 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 Scaling up Renewable Energy Program (SREP) is working to develop market for large scale Commercial Biogas and Municipal Solid Waste (MSW) to energy projects in Nepal. AEPC is supporting this new sector by conducting feasibility studies at potential municipalities and commercial business entities and providing various subsidy schemes based on size of 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 timeframe, 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 Gandaki Province based on the secondary data from the study reports from AEPC are presented in **Table 5-8.**

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

District	District population (2078)	Total Commercial/ Industrial Waste (tons/day)	Total Organic Municipal Waste (tons/day)	Total Organic Waste Production (tons/day)	Total Biogas Yield (cum/day)	Total Organic Waste Production "000" tons/Year	Bio gas in "000" cubic meter	Energy in "000" GJ per year
BAGLUNG **	250,554	2.46	12.80	15.26	786.70	5.57	287.15	5,742.91
GORKHA *	252,201	24.63	14.65	39.28	2,260.79	14.34	825.19	16,503.76
KASKI **	599,504	19.81	66.40	86.21	4,773.50	31.47	1,742.33	34,846.55
LAMJUNG *	153,480	14.99	8.92	23.91	1,375.83	8.73	502.18	10,043.53
MANANG *	5,645	0.55	0.33	0.88	50.60	0.32	18.47	369.38
MUSTANG *	14,596	1.43	0.85	2.27	130.84	0.83	47.76	955.15
MYAGDI *	107,372	10.49	6.24	16.72	962.50	6.10	351.31	7,026.28
NAWALPUR **	381,105	132.86	22.14	155.00	8,680.00	56.58	3,168.20	63,364.00
PARBAT *	132,703	12.96	7.71	20.67	1,189.58	7.54	434.20	8,683.95
SYANGJA **	254,965	20.03	8.10	28.13	2,197.40	10.27	802.05	16,041.02
TANAHUN **	327,620	5.99	12.70	18.69	873.20	6.82	318.72	6,374.36
Total	**2,479,745**	**246.19**	**160.83**	**407.02**	**23,280.94**	**148.56**	**8,497.54**	**169,950.89**

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

***Source data from of AEPC field study report.*

**Projected and calculated based on the AEPC field study report*

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

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

The W2E potential for Gorkha, Lamjung, Manang, Mustang, Myagdi and Parbat districts has been calculated based on the proportionating population density with reference to other districts since no field studies have been conducted in these districts yet.

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

From the table given above, it is seen that Manang and Mustang district had least W2E potential and Nawalpur and Kaskidistricts have high potential within the province. The total W2E potential energy is found to be 169,950 thousand GJ per year.

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 5-9.**

Table 5-9. Area of Different Crop in Districts (ha)

Districts	Area						
	Paddy	Maize	Wheat	Sugarcane	Buckwheat	Oil seed	Millet
Manang	0	0	198	0	270	3	0
Mustang	0	548	582	0	550	13	0
Gorkha	115,44	18,110	3,910	60	373	781	11,623
Lamjung	14,133	10,256	1,743	20	14	939	7,927
Tanahun	11,752	23,383	1,800	45	170	649	6,352
Kaski	23,286	14,638	6,500	0	13	629	14,789
Parbat	8,368	14,805	2,718	0	47	386	8,568
Syangja	15,997	28,164	4,550	26	217	882	16,515
Myagdi	3,782	9,794	3,141	3	140	4242	2,744
Baglung	5,272	21,165	7,562	0	81	952	18,608
Nawalpur	21,175	4,466	8,587	3,668	85	3,932	225
Total	**115,309**	**145,329**	**41,291**	**3,822**	**1,960**	**13,408**	**87,351**

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

Table 5-10. Energy from Agriculture Waste /Year

Districts	Residue of crops in tons							Total residue in tons	Energy produced in GJ
	Paddy	Maize	Wheat	Sugarcane	Buckwheat	Oil seed	Millet		
Manang	0	0	667.26	0	405	3.84	0	1,076	16,141
Mustang	0	2,986.6	1,961.34	0	825	16.64	0	5,789	86,843
Gorkha	68,109.6	98,699.5	13,176.7	1,442.4	559.5	999.6	22,083	205,071	3,076,066
Lamjung	83,384.7	55,895.2	5,873.91	480.8	21	1,201.9	15,061	161,918	2,428,782
Tanahun	69,336.8	127,437.3	6,066	1,081.8	255	830.7	12,068	217,076	3,256,147
Kaski	137,387.4	797,777.1	21,905	0	19.5	805.1	28,099	267,993	4,019,898
Parbat	49,371.2	80,687.2	9,159.6	0	70.5	494	16,279	156,061	2,340,928
Syangja	94,382.3	153,493.8	15,333.5	625	325.5	1,128.9	31,378	296,667	4,450,014
Myagdi	22,313.8	53,377.3	10,585.1	72.1	210	5,429.7	5,213	97,201	1,458,026
Baglung	31,104.8	115,349.2	25,483.9	0	121.5	1,218.5	35,355	208,633	3,129,498
Nawalpur	124,932.5	24,339.7	28,938.1	88,178.7	127.5	5,032.9	427	27,1977	4,0796,56
Total	**680,323.1**	**79,2043.0**	**139,150.6**	**91,880**	**2,940**	**17,162**	**165,966**	**1,889,466**	**28,342,002**

Table 5-10provides the estimate of total agriculture residue produced from different crops and energy produced from these agricultural residues. Total potential energy produced from such waste is 28,342 TJ. More than half of this energy comes from paddy and maize straw.

5.4 Petroleum Products

Petroleum drillingis being explored under the Department of Mines and Geology, GoN, butproven reserve of feasible petroleum products is yet to be found out in Nepal. All the petroleum products consumed in the country are imported from India. The only company that deals with import and sales of petroleum products – that include diesel, petrol, kerosene and LPG and others. The furnace oils and other oil residues are imported by the industries themselves. Thus, the supply of petroleum products is obtained from regional offices of Nepal Oil Corporation. District-wise sales data for 2077-78 is as shown in **Table 5-11.** All the units for MS, Diesel and SKO are in 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 consumptions may not tally properly. The sales data from NOC depot shows that approximately 7% total national sales of diesel, gasoline and kerosene are consumed in Gandaki Province, besides individual imports from other provinces.

Table 5-11. Petroleum Products Consumption in 2077-78 in Gandaki Province

Districts	MS	Diesel	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Baglung	1,468	4,967	101	-	-
Gorkha	1,504	6,376	-	-	-
Kaski	23,903	38,374	1,307	1,326	-
Lamjung	991	4,667	-	-	-
Mustang	-	72	-	-	-
Myagdi	794	4,620	-	-	-
Parbat	1,357	6,818	-	-	-
Syangja	3,353	11,785	326	-	-
Tanahun	7,816	30,589	16	-	-
Total	**41,186**	**108,267**	**1,750**	**1,326**	**-**

(Source: NOC 2022)

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

5.5 Electricity

5.5.1 Hydropower Potential

Nepal's theoretical hydropower potential has been estimated at about 83,000 MW and its technically and economically feasible potential of about 45,000 MW and 42,000 MW respectively (Shrestha, 1966). A study by Bajracharya (2015) shows the total theoretical estimation at annual mean flow to be 103,341 MW. The study carried out by WECS in 2019 for the estimation of hydropower potential shows the gross hydropower potential of 72,544 MW from three river basins: Koshi, Gandaki, and Karnali basin which covers 94% of the total gross potential of the country(WECS, 2019). Gross hydropower potential distributions in provinces based on the major three river basins are as shown in **Table 5-12.**Province-1, which includes most of the Koshi basin incorporates the highest hydropower potential (22,619 MW)- which is 31.2% of total hydropower potential. Madheshprovince incorporates the lowest hydropower potential (275 MW)-which is 0.4% of 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 5-12. 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	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 own generation, the Independent Power Purchasers (IPPs) significantly contribute to the national hydropower plants' development. The total national installed capacity from IPPs stands at 814.6MW. In addition, there is 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 from October 2021.

The province wise hydropower plants projects areas, being developed by NEA are shown in **Table 5-13.**

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

S.No.	Power Stations	District	Total Installed Capacity (MW)	FY 2077/78 (MWh)
NEA developed HPP				
Gandaki				
1	Kaligandaki 'A'	Syangja	144	817,712.86
2	Mid-Marsyangdi	Lamjung	70	398,846.30
3	Marsyandi	Tanahun	69	398,920.10
4	Modi	Parbat	14.8	60,470.50
5	Seti	Kaski	1.5	11,682.18
6	Tatopani	Myagdi	2	
		Total	**301.3**	
Under Construction Projects				
Gandaki				
1	Upper Modi A HEP	Kaski	42	
2	Upper Modi HEP	Kaski	18.2	
		Total	**60.2**	
NEA Planned and Proposed Projects				
Gandaki				
1	Uttar Ganga Storage HEP	Baglung	828	
2	Aadhikhola Storage HEP	Syangja	180	
3	BegnasRupa Pump Storage HEP	Kaski	150	
		Total	**1158**	

(DoED, 2023)

The IPPs operated, under construction and planned projects in four provinces are as shown in **Table 5-14**

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

	In operation	Under construction	Planned Projects
	Installed capacity MW	Installed capacity MW	capacity
Gandaki	498.28	1593.02	1091.02

5.5.2 Electricity Supply

The district wise electricity supply status as obtained from Nepal Electricity Authority for Gandaki Province is as shown in **Table 5-15** along with its use in economic sectors. It shows Nawalpurand Kaski have a comparatively high consumption of electricity due mainly to the number of industries located in the districts. Most of the electricity is consumed in the residential sector (48%), followed by commercial and industrial sectors with 27% and 25% respectively. The agricultural and transport sectors consumed less than 1% of grid electricity.

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

	Agriculture	Commercial	Industry	Residential	Transport	In TJ
Baglung	0.00	17.10	3.90	44.29	-	65.29
Gorkha	0.66	34.36	6.72	64.41	0.11	106.27
Kaski	0.54	291.76	121.28	570.43	-	984.01
Lamjung	0.00	97.85	0.22	0.77	-	98.85
Manang	-	-	-	-	-	-
Mustang	-	-	-	-	-	-
Myagdi	0.12	24.35	2.48	26.66	-	53.62
Nawalpur	6.18	49.77	382.16	221.94	-	660.05
Parbat	0.03	25.40	4.54	30.09	0.05	60.10
Syangja	0.02	24.88	4.31	38.35	-	67.56
Tanahun	0.91	40.74	41.51	99.83	-	182.99
Total	**8.46**	**606.22**	**567.13**	**1,096.78**	**0.16**	**2,278.74**

(NEA, 2022)

5.6 Modern Renewable Energy Sources- Solar & Other Renewables

Alternative Energy Promotion Centre (AEPC) has been promoting renewable energy technologies in Nepal 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, 371 nos. of projects are implemented in Gandaki Province generating 7.14 MW of electricity benefitting 67,359 nos. of rural households. Baglung and Gorkha have comparatively more beneficiary households covering 50.37% and 15.62% of the total provincial beneficiary while Mustang had not benefitted at all. According to AEPC, 204 nos. of improved water mills, 48,372 nos. of solar home system units, 223 nos. of institutional solar PV System generating 391.53 kWp, 50 solar irrigation systems, and 27 solar water pumping systems has been installed which covers 1.8%, 6.1%, 7.3%, 2.3% and 14.4% 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, around 13% of the installation has been done in Gandaki Province, i.e, 79,755 Nos. of domestic biogas plants, 106,802 mud ICS and 22,701 metallic ICS (**Table 5-16**).

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

Technologies	Micro Hydro Projects			Improved Water Mill	Solar Home System	Institutional Solar Photovoltaic System	
District	**No. Projects**	**kW**	**HHs**	**Numbers**	**Numbers**	**Numbers**	**Wp**
Baglung	145	3,646	33,931	40	4,074	25	92,000
Gorkha	57	1,016	10,521	57	5,989	53	67370
Kaski	9	248	1,876	55	1,792	12	24000
Lamjung	24	439	3,819	12	5,402	20	41500
Manang	12	299	1,688	5	135	-	-
Mustang	-	-	-	5	1333	31	27510
Myagdi	38	562	5,475	23	4851	48	64145
Nawalpur	44	302	4,307	-	5056	9	25500
Parbat	13	194	1,923	5	4504	2	4500
Syangja	7	157	1,464	1	4059	20	39000
Tanahunn	22	272	2,355	1	11177	3	6000
Grand Total	**371**	**7,135**	**67,359**	**204**	**48372**	**223**	**391,525**

(AEPC, 2021)

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**
Baglung	-	3	999	2	26,465	509
Gorkha	-	-	9035	2	8,865	12372
Kaski	1	2	19100	38	2,855	1594
Lamjung	1	-	12083	12	4,947	1,886
Manang	-	-	-	-	16	68
Mustang	-	-	14	-	-	3
Myagdi	-	1	1,078	2	11,290	1,456
Nawalpur	41	1	6,025	3	1,847	292
Parbat	-	-	989	2	16,792	388
Syangja	2	5	9,871	5	19,739	805
Tanahunn	5	15	20,561	18	13,986	3,328
Grand Total	**50**	**27**	**79,755**	**84**	**106,802**	**22,701**

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 as obtained from the survey shows that in Gandaki Province there is sufficient supply of fuelwood, agri-residue, and animal waste to meet its demand for household purposes. Similarly, for the modern energy supply, biogas and solar are two prominent sources. Biogasplants of various sizes are installed in different districts supplying enough biogas energy which is predominantly used for cooking proposes in residential sector. Regarding solar energy, the small and institutional solar home system installed at household level also supplied adequate energy which is used for lighting purposes at household level (**Table 5-17).** Details of household energy production of each district are given in annex.

Table 5-17. Household Energy Production

(In TJ)

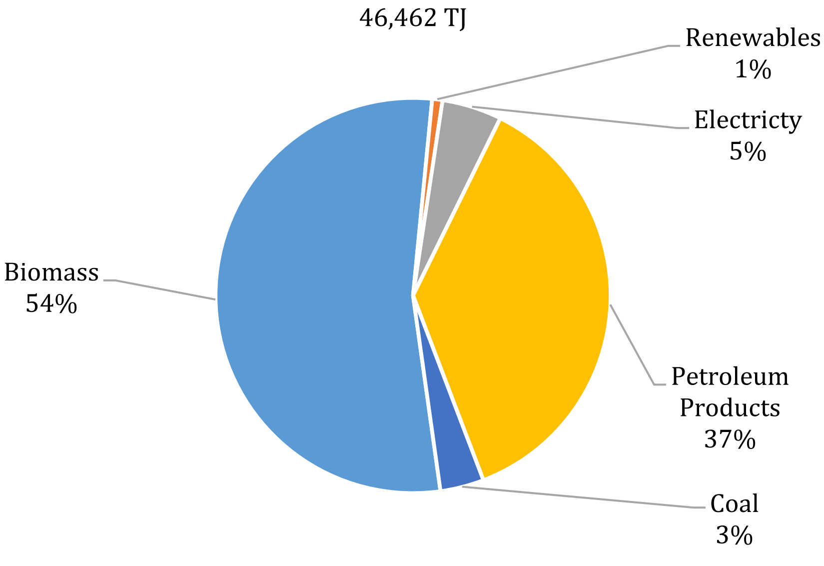
Fuel sources	
Fuelwood	7,027.45
Agriresidue	3.07
Animal waste	-
Biogas	570.49
Solar PV	6.14

(Calculated from survey data)

6. Energy Consumption in 2021/2022

The total final energy consumption (FEC) in Gandaki Province was found to be 46,462 TJ. Among the six sectors, the residential sector is the highest energy-consuming sector followed by industries. However, the amount of energy consumed in both the sectorsis nearly equal. These results are an indication of energy efficiency improvement as well as the growinguse of energy in productive sectors. This can be seen in the energy mix as well. The highest share of energy consumed, although is still biomass (54%), the lower share of it in FEC shows that the use of modern energy has been increasing. With the increase in demand for energy in industrial and other economic sectors, the consumption of petroleum products has increased significantly, taking a share of 37% in FEC. The primary reason behind this change in energy pattern is seemingly due to energy transition and energy efficiency improvement, which is in line with the report by IEAfor developing countries (IEA, 2018).

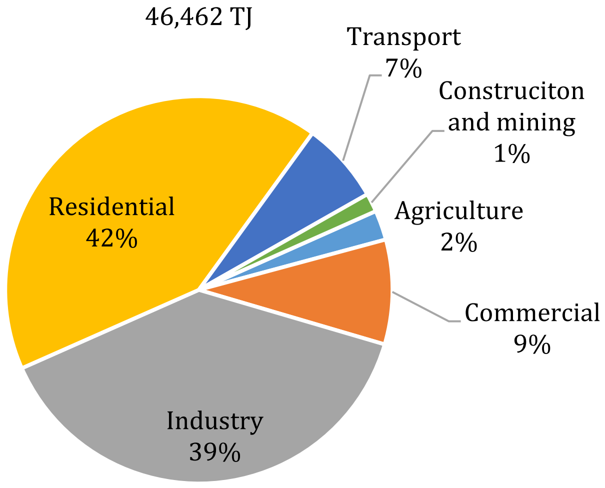
In Gandaki Province, the use of fuelwood is still prevalent among biomass (**Figure 6-1**). But the use of fuelwood for thermal purposes has shifted. Hence the consumption of diesel, furnace oil and coal for thermal use is seeing an increase. Due to higher consumption for thermal purposes such as heating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



(Survey, 2022)

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

Figure 6-2 also indicates the change in the consumption pattern in different economic sectors. With the residential and the industrial sectors being the highest energy-consuming sectors, the use of biomass and fossil fuels are prevalent in these sectors. The commercial sector is third at 9% followed by the transport sector at 7%. Although mechanization in the agricultural sector is gaining popularity, the use of fuel in this sector is very low at about 2%. This can indicate that, for a country like Nepal, which has vast fertile lands, there could be ample opportunity for economic development by use of efficient processes and more emphasis on mechanization in agricultural sector.



(Survey, 2022)

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

The energy mix by fuel type in different sectors can be seen in **Table 6-1.**The major portion of the traditional biomass is consumed in the residential sector.Meanwhile, the use of agricultural residue and animal waste are very low – firstly due to the availability of commercial fuels, and secondly, animal wastes go for biogas as well as manure making. However, large amounts of agricultural residues are seen to be being used in industries for thermal purposes – mainly due to cheaper prices and local/regional availability. The residential sector is the highest use of electricity as well. However, the use of electricity in commercial and industrial sectors is also significant. Meanwhile, although petrol is used largely in transport for vehicles, the largest consumer of diesel isthe 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.

Table 6-1. Annual Energy Consumption in Gandaki Province by Sector and Fuel Type in 2022

in TJ

	Renewables								**Non - renewables**						
	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**	**Total**
Agriculture	-	-	-	-	-	0.01	11.88	3.24	1,132.77	-	-	-	-	-	1,147.90
Commercial	2,946.96	106.76	92.90	-	-	61.65	610.51	-	-	-	-	-	194.98	50.09	4,063.84
Industry	1,954.69	3,843.25	-	-	-	-	626.28	644.01	7,047.91	-	2,281.34	-	29.84	1,608.21	18,035.52
Residential	16,013.01	26.00	-	323.89	-	6.16	999.23	-	-	3.19	-	-	1,964.15	1.48	19,337.10
Transport	-	-	-	-	-	-	0.05	1,025.18	1,698.27	-	-	435.12	-	-	3,158.61
Construction and mining	-	-	-	-	-	-	24.02	15.35	592.19	0.01	-	-	87.55	-	719.12
Total	**20,914.65**	**3,976.01**	**92.90**	**323.89**	**-**	**67.81**	**2,271.97**	**1,687.79**	**10,471.13**	**3.20**	**2,281.34**	**435.12**	**2,276.51**	**1,659.78**	**46,462.08**

(Survey, 2022)

Figure 6-3 illustrates the flow of energy in the Gandaki Province. It is quite visible that the largest share of energy is from primary solid biomass followed by petroleum products in 2022.

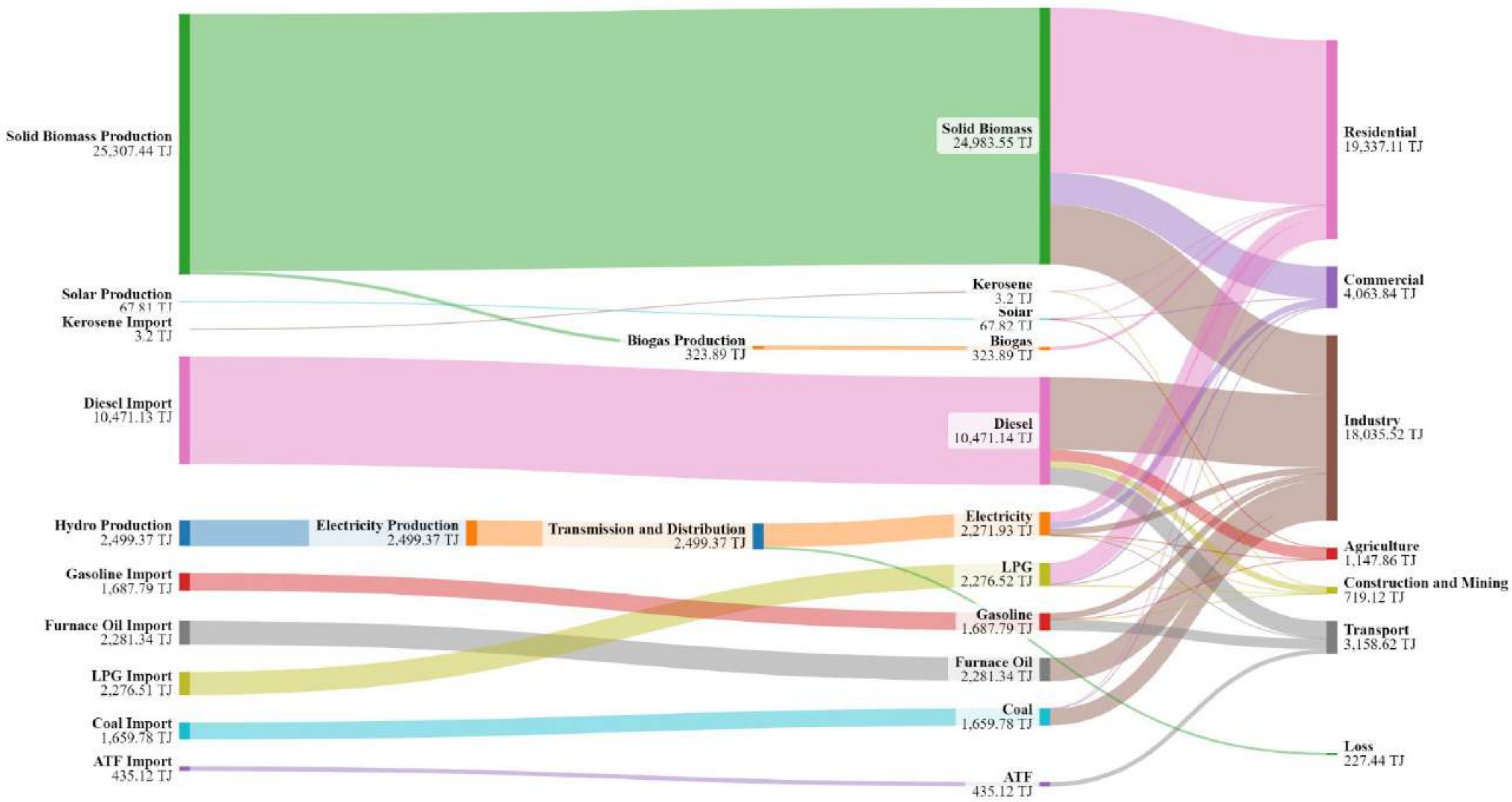


Figure 6-3. Energy Flow in Gandaki Province (Sankey Diagram)

Table 6-2 shows the energy consumption indicators which highlight the status of energy consumption in Gandaki Province. The total final energy consumption per capita of 18.74 GJ is lower than the national average. This is due to the usage of more efficient technologies on the one hand while on the other there is the lower amount of energy consumed in the residential sector as opposed to other less developed provinces. The electricity consumption per capita comes lower than the national average. The residential electricity consumption per household lies in tier3 of the multi-tier framework and 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	18.74
Energy per GVA	GJ per million NRs	124
Share of modern and new renewable energy		5.73%
Electricity Consumption (Total)	kWh per capita	262
Electricity Consumption (Residential)	kWh per HH	410

(Survey, 2022)

The energy consumption at the district levels is provided in **Annex**.

6.1 Energy Consumption in Gandaki Province by Ecological Regions

The ecological distribution of energy consumption is affected by population, as well as energy access. As seen from **Table 6-3,**the mountain region has the least amount of energy consumed – primarily due to the least number of people in the region. On the contrary, even though the terai region has a small area in this province, the population as well as other economic activities are higher. Thus, the energy consumption is higher in terai, while the hilly region has the highest energy consumption. In terms of energy types, the use of traditional biomass is dominant in hilly regions. Meanwhile, commercial fuels such as petroleum products and electricity are highly used in hilly and terai regions. Meanwhile, due to higher usage in industry as well, diesel consumption is a little higher in the terai region. Sector-wise, energy consumption is yet again impacted by population and the presence of economic activity. And hence, the energy consumption share is high in hilly regions. However, due to easier access and higher mechanization, energy consumption in the agriculture sector is higher in the terai region. The hilly and mountain regions are dependent upon ground water and rainwater for irrigation and drought animals for farming activities.

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

		Fuelwood	Agricultural residue	Animal waste	Coal	Kerosene	LPG	Diesel	Gasoline	ATF	Furnace oil	Electricity	biogas	briquettes	Solar thermal	Solar PV	Total
Mountain		**483.41**	**12.58**	**-**	**-**	**-**	**16.73**	**16.55**	**-**	**-**	**6.88**	**18.54**	**-**	**-**	**0.00**	**5.42**	**560.11**
	Agriculture		-	-	-	-	-	0.71	-	-	-	0.02	-	-	-	-	**0.73**
	Commercial	281.02	12.26	-	-	-	4.00	-	-	-		1.79	-	-	0.00	5.23	**304.31**
	Industrial	-	-	-	-	-	0.05	15.84	-	-	6.88	14.15	-	-	-	-	**36.92**
	Residential	202.39	0.33	-	-	-	12.68	-	-	-		2.57	-	-	0.00	0.19	**218.16**
Hills		**19,215.30**	**1,707.02**	**92.90**	**1,548.85**	**1.98**	**1,884.27**	**3,802.18**	**647.26**	**-**	**2,274.47**	**1,669.82**	**320.28**	**-**	**0.11**	**60.68**	**33,225.13**
	Agriculture		-	-	-	-	-	366.84	3.24	-	-	3.77	-	-	-	0.01	**373.86**
	Commercial	2,656.70	94.50	92.90	50.09	-	179.87	-	-	-		568.43	-	-	0.06	55.40	**3,697.94**
	Industrial	1,951.35	1,586.85	-	1,497.28	-	29.79	3,435.34	644.01	-	2,274.47	303.24	-	-	-	-	**11,722.34**
	Residential	14,607.26	25.68	-	1.48	1.98	1,674.60	-	-	-		794.37	320.28	-	0.05	5.28	**17,430.99**
Terai		**1,215.94**	**2,256.40**	**-**	**110.93**	**1.21**	**287.97**	**4,361.94**	**-**	**-**	**-**	**559.54**	**3.61**	**-**	**0.00**	**1.59**	**8,799.11**
	Agriculture		-		-	-	-	765.21	-		-	8.10	-	-	-	-	**773.31**
	Commercial	9.24	-	-	-	-	11.11	-	-	-		-	-	-	-	0.96	**61.59**
	Industrial	3.34	2,256.40	-	110.93	-	-	3,596.72	-	-	-	-	-	-	-	-	**6,276.26**
	Residential	1,203.36	-	-	-	1.21	276.86	-	-	-		202.28	3.61	-	0.00	0.64	**1,687.95**
Province																	
	Transport		-	-	-	-	-	1,698.27	1,025.18	435.12	-	-	-	-	-	-	**3,158.56**
	Construction and mining			-	-	0.01	87.55	592.19	15.35	-	-	24.02	-	-	-	-	**719.12**
Grand total		**20,914.65**	**3,976.01**	**92.90**	**1,659.78**	**3.20**	**2,276.51**	**10,471.13**	**1,687.79**	**435.12**	**2,281.34**	**2,271.92**	**323.89**	**-**	**0.12**	**67.70**	**46,462.03**

6.2 Agriculture Sector

The agriculture sector in Gandaki Province only consumes about 1,147 TJ and among this, the use of diesel for farm machinery is very highcompared tothe consumption of petrol and electricity (**Figure 6-4**). Although the penetration of solar pumping systems for irrigation is gaining popularity, its use is nominal. It is mainly due to geographical difficulty in hilly and mountainous regions.

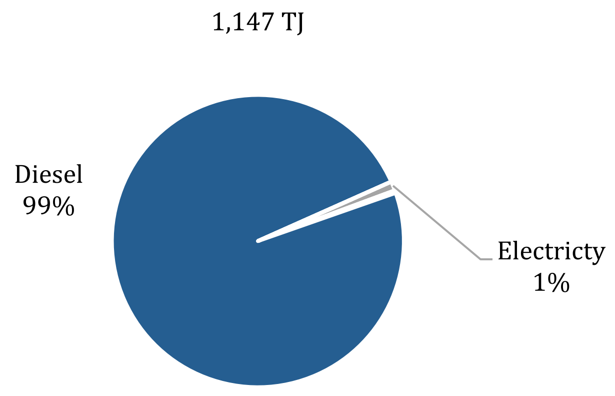


Figure 6-4. Energy Mix in Agriculture Sector

From **Table 6-4** most of the diesel is used for farm machinery. A large portion of irrigation in Gandaki Province is dependent upon ground and rainwater. Meanwhile, electricity is mostly used for water pumping and very less for other farming machinery. Solar is limited to irrigation purposes only. The largest amount of energy is used for tillage, which is also aided by using draught animals, mostly in mountainous regions.

Table 6-4. Energy Consumptions in Agriculture Sector

In TJ

	Water pumping	Tilling	Threshing	Total
Petrol	-	-	3.24	**3.24**
Diesel	321.08	698.25	113.44	**1,132.77**
Electricity	11.88	0.00	0.00	**11.88**
Solar	0.01	-	-	**0.01**
Total	**332.97**	**698.25**	**116.68**	**1,147.90**

Ecologically, the largest amount of energy is consumed in the terai region for all purposes **(Table 6-5)** In contrary to hills and mountain regions, irrigation is largely done by diesel pumps. Meanwhile, the upper regions, being more dependent upon rainwater, use less energy for irrigation. Tillage is equally important and thus, is done by diesel tractors in both hilly andterai 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 by End Uses in Agriculture Sector by Ecological Region

in TJ

		Water pumping	Tilling	Threshing	Total
Mountain		**0.02**	**0.71**	**-**	**0.73**
	Petrol	-	-	-	-
	Diesel	-	0.71	-	0.71
	Electricity	0.02	-	-	0.02
	Solar	-	-	-	-
Hills		**3.77**	**353.89**	**16.20**	**373.86**
	Petrol	-	-	3.24	3.24
	Diesel	-	353.89	12.96	366.84
	Electricity	3.77	0.00	0.00	3.77
	Solar	0.01	-	-	0.01
Terai		**329.18**	**343.65**	**100.48**	**773.31**
	Petrol	-	-	-	-
	Diesel	321.08	343.65	100.48	765.21
	Electricity	8.10	-	-	8.10
	Solar	-	-	-	-
	Grand total	**332.97**	**698.25**	**116.68**	**1,147.90**

6.3 Commercial Sector

The commercial sector is the third most energy-consuming sector, at 4,063 TJ. Althoughthe commercial sector is expected to use commercial forms of energy, the use of biomass is still prevailing in this sector in Gandaki Province (**Figure 6-5**). This is used primarily in hotels, and restaurants as well as in barracks, and community centers for cooking purposes. Some portions of biomass are used for space heating in colder seasons as well. The electricity is used for electrical appliances and lighting as well as space cooling purposes.

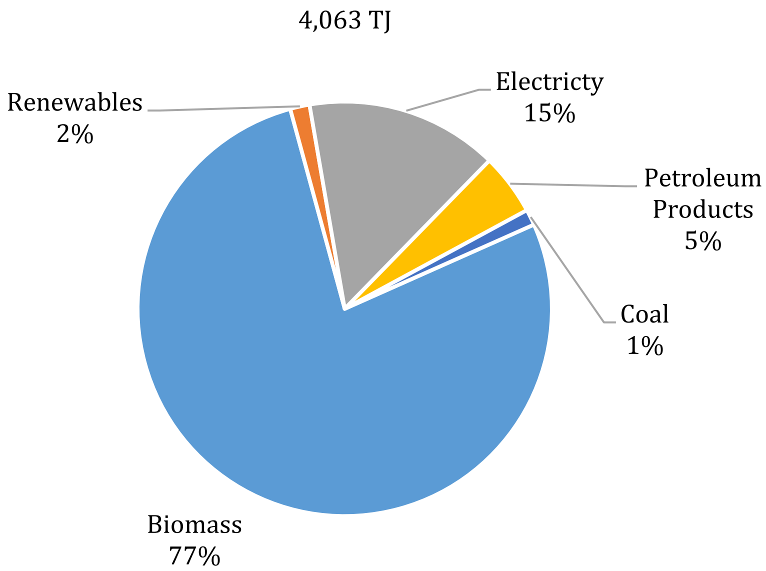


Figure 6-5. Energy Mix in Commercial Sector

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 for lighting is good though lower thanthe use of grid electricity.

Table 6-6. Energy Consumption in Commercial Sector

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	Other use	Total
Fuelwood	2,639.32	65.04	208.97	-	-	-	33.63	-	**2,946.96**
Agricultural residue	106.76	-	-	-	-	-	-	-	**106.76**
Animal waste	92.90	-	-	-	-	-	-	-	**92.90**
Coal	50.09	-	-	-	-	-	-	-	**50.09**
LPG	173.46	9.61	0.30	-	-	-	11.61	-	**194.98**
Electricity	85.99	1.64	16.22	14.08	75.42	417.16	-	-	**610.51**
Solar thermal	-	0.06	-	-	-	-	-	-	**0.06**
Solar PV	-	-	-	-	16.82	44.76	-	-	**61.59**
Total	**3,148.52**	**76.34**	**225.49**	**14.08**	**92.24**	**461.92**	**45.24**	**-**	**4,063.84**

Subsector-wise, the largest amount of energy is used in the accommodation and food service sector which comprises mostly of hotels and restaurants. They are highly reliant on biomass for energy even though the use of LPG is also significant to others (**Table 6-7**). The financial and real estate sector uses the least amount of energy as their primary consumptionis 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	579.42	1,136.21	-	1,144.06	87.27	**2,946.96**
Agricultural residue	16.62	79.72	-	5.60	4.81	**106.76**
Animal waste	42.44	49.15	-	1.31	-	**92.90**
Coal	29.56	12.06	-	8.47	-	**50.09**
kerosene	-	-	-	-	-	**-**
LPG	49.07	113.76	2.03	21.04	9.09	**194.98**
Diesel	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	**-**
Electricity	267.03	175.99	14.45	117.40	35.65	**610.51**
biogas	-	-	-	-	-	**-**
briquettes	-	-	-	-	-	**-**
Solar thermal	-	0.06	-	-	-	**0.06**
Solar PV	7.76	0.79	0.84	50.48	1.72	**61.59**
Total	**991.90**	**1,567.75**	**17.31**	**1,348.35**	**138.52**	**4,063.84**

As for energy-using activities in sub-sectors, the highest amount of energy is used for cooking (**Table 6-8**), which is majorly in biomass as seen in**Table 6-6 and Table 6-7**. Space heating is largely used by accommodation service institutions.

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	726.63	13.93	6.84	3.07	46.47	191.77	3.20	-	**991.90**
Accommodation	1,169.41	53.07	210.86	3.10	16.02	105.63	9.65	-	**1,567.75**
Financial	2.55	-	0.30	1.98	3.01	9.46	-	-	**17.31**
Social	1,172.58	6.34	5.85	5.37	21.95	127.70	8.58	-	**1,348.35**
Others	77.35	3.01	1.64	0.57	4.79	27.37	23.81	-	**138.52**
Total	**3,148.52**	**76.34**	**225.49**	**14.08**	**92.24**	**461.92**	**45.24**	**-**	**4,063.84**

Ecologically, the hills consume a larger portion of energy in the commercial sector due to the presence of a larger number of sales and service-oriented institutions (**Table 6-9 and 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	Total
Mountain	58.31	29.98	209.09	0.03	2.62	4.29	-	**304.31**
Hills	3,069.86	46.33	16.41	10.04	85.64	424.42	45.24	**3,697.94**
Terai	20.35	0.04	-	4.02	3.98	33.21	-	**61.59**
Total	**3,148.52**	**76.34**	**225.49**	**14.08**	**92.24**	**461.92**	**45.24**	**4,063.84**

Fuel wise also, a higher amount of energy is used in the hilly region (**Table 6-10**). The use of solar thermal for water heating is found in hilly regions and very few in the mountain regions. There is no significant quantity of solar water heating found in the terai region.

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

	Fuelwood	Agricultural residue	Animal waste	Coal	LPG	Electricity	Solar thermal	Solar PV	Total
Mountain	281.02	12.26	-	-	4.00	1.79	0.00	5.23	**304.31**
Hills	2,656.70	94.50	92.90	50.09	179.87	568.43	0.06	55.40	**3,697.94**
Terai	9.24	-	-	-	11.11	40.28	-	0.96	**61.59**
Total	**2,946.96**	**106.76**	**92.90**	**50.09**	**194.98**	**610.51**	**0.06**	**61.59**	**4,063.84**

6.4 Residential Sector

The residential sector is the highest energy-consuming sector in the Gandaki Province with a total of 19,337 TJ. In the energy mix, the use of biomass is dominant in this province followed by LPG and electricity (**Figure 6-6**). The use of electricity is not able to take a higher share, majorly due to the problem of power supply reliability and voltage fluctuations.

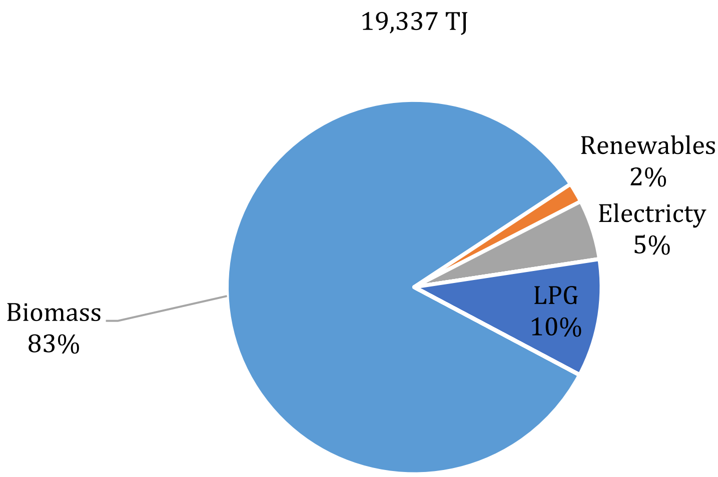


Figure 6-6. Energy Mix in Residential Sector

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

Table 6-11. Energy Consumptions in Residential Sector

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	13,713.88	1,125.66	125.47	-	-	-	1,047.99	**16,013.01**
Agricultural residue	26.00	-	-	-	-	-	-	**26.00**
Animal waste	-	-	-	-	-	-	-	**-**
Coal	0.45	0.91	-	-	-	-	0.12	**1.48**
kerosene	0.82	-	-	-	-	-	2.37	**3.19**
LPG	1,828.10	42.34	-	-	-	-	93.70	**1,964.15**
Electricity	147.93	-	0.00	19.13	124.80	698.91	8.46	**999.23**
Biogas	305.62	15.82	-	-	2.20	-	0.25	**323.89**
Briquettes	-	-	-	-	-	-	-	**-**
Solar thermal	-	0.05	-	-	-	-	-	**0.05**
Solar PV	-	-	-	-	6.10	-	-	**6.10**
Total	**16,022.81**	**1,184.79**	**125.47**	**19.13**	**133.10**	**698.91**	**1,152.88**	**19,337.10**

Although the population is lower in rural municipalities, the amount of energy used is higher in rural areas (**Table 6-12 and Table 6-13).**This is majorly due to the use of inefficient technologies in rural areas. 90% 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.

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

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	9,115.06	219.18	122.85	-	-	-	130.39	**9,587.48**
Agricultural residue	3.07	-	-	-	-	-	-	**3.07**
Animal waste	-	-	-	-	-	-	-	**-**
Coal	0.45	0.91	-	-	-	-	-	**1.36**
kerosene	0.82	-	-	-	-	-	0.17	**0.99**
LPG	391.71	13.10	-	-	-	-	3.08	**407.89**
Diesel	-	-	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	-	-	**-**
Electricity	13.90	-	0.00	0.33	25.44	48.37	3.82	**91.87**
Biogas	101.33	-	-	-	2.20	-	-	**103.53**
Briquettes	-	-	-	-	-	-	-	**-**
Solar thermal	-	0.00	-	-	-	-	-	**0.00**
Solar PV	-	-	-	-	4.88	-	-	**4.88**
Total	**9,626.36**	**233.19**	**122.85**	**0.33**	**32.53**	**48.37**	**137.46**	**10,201.09**

In comparison to rural areas, urban areas are highly dependent upon commercial forms of energy. Although the share of biomass is still predominant in urban regions as well, the consumption of LPG and electricity isalso significant. The use of biogas in urban areas is also high. It isprimarily because ofchangesin administrative divisions and establishments of new urban municipalities from rural ones.

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

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	4,598.82	906.48	2.62	-	-	-	917.60	**6,425.52**
Agricultural residue	22.93	-	-	-	-	-	-	**22.93**
Animal waste	-	-	-	-	-	-	-	**-**
Coal	-	-	-	-	-	-	0.12	**0.12**
kerosene	-	-	-	-	-	-	2.20	**2.20**
LPG	1,436.39	29.25	-	-	-	-	90.61	**1,556.25**
Diesel	-	-	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	-	-	**-**
Electricity	134.02	-	-	18.80	99.35	650.54	4.64	**907.35**
Biogas	204.28	15.82	-	-	-	-	0.25	**220.35**
Briquettes	-	-	-	-	-	-	-	**-**
Solar thermal	-	0.05	-	-	-	-	-	**0.05**
Solar PV	-	-	-	-	1.22	-	-	**1.22**
Total	**6,396.45**	**951.60**	**2.62**	**18.80**	**100.57**	**650.54**	**1,015.42**	**9,136.00**

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.**Peculiarly, the hilly region uses a significant amount of energy for other uses as well in comparison to the mountain and Terai regions.

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

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Other uses	Total
Mountain	194.36	18.24	2.78	0.00	1.26	1.50	0.03	**218.16**
Hills	14,332.63	1,166.55	122.70	8.09	103.54	545.82	1,151.65	**17,430.99**
Terai	1,495.82	0.00	-	11.04	28.30	151.59	1.21	**1,687.95**
Total	**16,022.81**	**1,184.79**	**125.47**	**19.13**	**133.10**	**698.91**	**1,152.88**	**19,337.10**

In terms of energy type, it is observed that hilly regions predominantly use biomass as well as other forms of energy. The highest amount of energy is seen to be used in the Kaski district in the hilly region.

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

In TJ

	Fuelwood	Agricultural residue	Coal	Kerosene	LPG	Electricity	Biogas	Solar thermal	Solar PV	Total
Mountain	202.39	0.33	-	-	12.68	2.57	-	0.00	0.19	**218.16**
Hills	14,607.26	25.68	1.48	1.98	1,674.60	794.37	320.28	0.05	5.28	**17,430.99**
Terai	1,203.36	-	-	1.21	276.86	202.28	3.61	0.00	0.64	**1,687.95**
Total	**16,013.01**	**26.00**	**1.48**	**3.19**	**1,964.15**	**999.23**	**323.89**	**0.05**	**6.10**	**19,337.10**

6.5 Industrial Sector

The industrial sector consumed 18,035TJ of energy in Gandaki Province. The energy mix in the industrial sector is shown in **Figure 6-7.**Petroleum products, mainly diesel,are the major sources of fuel used for thermal purposes as well as in diesel generators for electricity generationand motive power. On the other hand, agri-residue and fuelwood are also used in significant amount for heating purposesmainly in the bricks and clay industries, food and beverage, wood products and paper industries. Whereas some industries also use furnace oil for thermal uses. Coal is mainly consumed at large in the brick and cement industries. With the gradual shift to clean energy, electricity usage has increased to some extent in industries reaching its share to 3%.

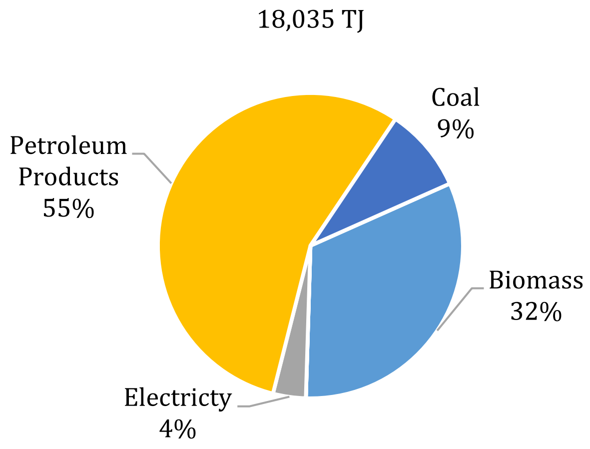


Figure 6-7. Energy Mix in Industrial Sector

Table 6-16 shows the consumption of energy types for different end uses. It clearly indicates the higher use of energy 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 of electricity generation. The increase in electricity consumption comes mainly from the shift to electric motor equipment.

Table 6-16. Energy Consumption in Industry Sector in TJ

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Fuelwood	-	855.06	401.00	-	698.62	**1,954.69**
Agriresidue	-	2,573.72	1,269.52	-	-	**3,843.25**
Coal	-	254.05	342.87	-	1,011.29	**1,608.21**
kerosene	-	-	-	-	-	**-**
LPG	-	-	6.59	-	23.25	**29.84**
Diesel	-	-	418.95	818.14	5,810.82	**7,047.91**
Gasoline	-	-	-	644.01	-	**644.01**
Furnace oil	-	-	2,281.34	-	-	**2,281.34**
Electricity	21.85	102.33	34.54	305.37	162.19	**626.28**
Total	**21.85**	**3,785.17**	**4,754.81**	**1,767.52**	**7,706.17**	**18,035.52**

(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, mechanical engineering industries, and bricks and structural clay products consumed comparatively higher energy consuming 10,511TJ, 4,631 TJ, and 2,078 TJ respectively. These three types of industries consumed 95% of the total energy consumed in the sector. They consumed diesel, furnace oil, fuelwood, and agri-residue as the major sources of energy.

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

	Fuelwood	Agricultural residue	Coal	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Food Beverage and Tobacco	1,405.82	3,842.74	-	8.05	2,676.75	-	2,263.92	313.41	**10,510.69**
Textile and Leather Goods	-	-	-	-	-	-	-	15.10	**15.10**
Chemical Rubber and Plastic	-	-	-	-	79.02	-	-	51.41	**130.43**
Mechanical Engineering and Manufacturing	-	-	611.09	17.71	3,276.98	644.01	-	81.01	**4,630.80**
Electrical Engineering Products	-	-	-	-	-	-	-	23.84	**23.84**
Wood Products and Paper	-	-	-	1.62	174.56	-	-	77.95	**254.14**
Bricks & Structural Clay Products	319.97	0.50	997.12	2.27	696.24	-	17.42	44.72	**2,078.24**
Cement & Nonmetallic Products	-	-	-	0.07	-	-	-	0.80	**0.87**
Other Manufacturing	228.90	-	-	0.12	144.36	-	-	18.03	**391.41**
Total	**1,954.69**	**3,843.25**	**1,608.21**	**29.84**	**7,047.91**	**644.01**	**2,281.34**	**626.28**	**18,035.52**

(Survey 2022)

Table 6-18 shows energy consumption in the industrial subsectors by its end-use services. It shows that other uses, which is mainly electricity generation from diesel generators used almost 43% of total energy consumption in the sector, followed by process heating and boilers. The major energy-consuming industries in Gandaki Province are the food and beverage industries. They use primarily solid biomass for their boilers and furnaces.

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

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Food Beverage and Tobacco	6.76	3,371.80	3,753.91	423.65	2,954.57	**10,510.69**
Textile and Leather Goods	0.11	-	0.13	4.13	10.73	**15.10**
Chemical Rubber and Plastic	0.35	-	18.29	-	111.79	**130.43**
Mechanical Engineering and Manufacturing	2.78	-	-	766.28	3,861.73	**4,630.80**
Electrical Engineering Products	0.96	-	-	13.72	9.16	**23.84**
Wood Products and Paper	3.78	0.23	1.91	67.16	181.06	**254.14**
Bricks & Structural Clay Products	6.78	413.14	609.68	487.10	561.53	**2,078.24**
Cement and Non-metallic Products	0.02	-	-	0.76	0.09	**0.87**
Other Manufacturing	0.31	-	370.87	4.72	15.51	**391.41**
Total	**21.85**	**3,785.17**	**4,754.81**	**1,767.52**	**7,706.17**	**18,035.52**

(Survey 2022)

Table 6-19 shows fuel-wise energy consumption by ecological region in Gandaki Province. Kaski and Nawalpur are the two major industrial hubs of Gandaki Province consuming more than 80% of the total energy in the industrial sector of the province. The mountainous region covers two districts namely Manang and Mustang where the industrial activities are minimal, thus consuming less than 1% of the total consumption. On the other hand, the hilly region consists of 8 districts and consumed almost 65% of the total consumption in the province. In contrast, the Terai region consists of only one district i.e. Nawalpur but consumed almost 35% of the total consumption as the district lies in the major industrial belt.

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	6.05	-	22.76	8.10	-	**36.92**
Hills	11.12	2,677.07	3,362.64	1,147.59	4,523.93	**11,722.34**
Terai	4.67	1,108.10	1,369.41	611.83	3,182.25	**6,276.26**
Total	**21.85**	**3,785.17**	**4,754.81**	**1,767.52**	**7,706.17**	**18,035.52**

(Survey 2022)

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

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

	Fuelwood	Agriresidue	Coal	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Mountain	-	-	-	0.05	15.84	-	6.88	14.15	**36.92**
Hills	1,951.35	1,586.85	1,497.28	29.79	3,435.34	644.01	2,274.47	303.24	**11,722.34**
Terai	3.34	2,256.40	110.93	-	3,596.72	-	-	308.88	**6,276.26**
Total	**1,954.69**	**3,843.25**	**1,608.21**	**29.84**	**7,047.91**	**644.01**	**2,281.34**	**626.28**	**18,035.52**

(Survey 2022)

A huge amount of heat energy is obtained from fossil fuels – primarily from agriculture residue, fuelwood, 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 used for thermal uses in addition to use in motive power. The grid electricity consumption share however is only 4% in Gandaki Province industries. 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 palpable signs of 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 is only one international airport under operation currently. However, the construction of two other international airports is under construction phase. Water transport is not yet popular in Nepal. But cable transport like cable cars, ropeways, and twin crossings are still in use in many parts of Nepal. In this energy consumption survey, for Gandaki 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-uses
Service Type		
Private Personal	car, jeep, van, motorcycle, bus, minibus, tempo, etc.	Passenger
Private Institutional	car, jeep, van, pickup, etc.	Passenger/Freight
Public Local-Short Distance	Bus, minibus, jeep, van, tempo, etc.	Passenger
Public Long Distance	Bus, minibus, jeep, van,etc..	Passenger
Freight	Truck, minitruck, pick-up, cargo van	Freight
Fuel type		
Diesel	car, jeep, van,bus, minibus,etc.	Passenger/Freight
Gasoline	car, jeep, van, motorcycle,etc.	Passenger/Freight
LPG	Tempo	Passenger
Electric	Rickshaw	Passenger

Aviation

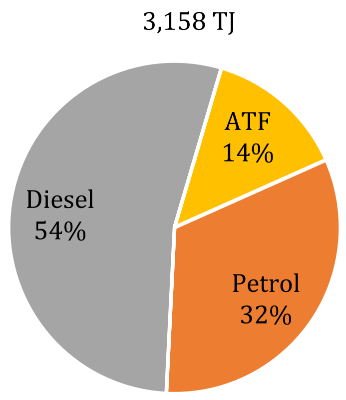
There are two airports in operation where domestic flights take place. The data regarding aircraft are published by the Civil Aviation Authority of Nepal (CAAN). The data shows the total aircraft movement, passenger movement and cargo movement as given in **Table 6-22.**

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

	Aircraft movement	Passenger movement	Cargo movement (in kg)
Pokhara	39,920	720,714	135,506
Jomsom	4,154	55,651	7,198
Gandaki Province	44,074	776,365	142,704

6.6.1 Transport Sector Energy Consumption by Fuel Types

The transport sector consumed 3,158 TJ energy. The energy mix in the transport sector is shown in **Figure 6-8**. It shows high consumption of diesel as most of the public passenger vehicles and all the freight vehicles are diesel- operated and are also less energy efficient compared to private vehicles. Consequently, about 43% of total diesel and 75% of total petrol salesin the province are solely used for transport activities. The increasing domestic air transport is vivid 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 vehiclesis 20%, that of private passenger vehicles is 39%, freight vehicle is 28%, and the remaining by air transport. Public passengers consumed 37% of the total diesel consumed in the sector as almost all public vehicles are diesel operated. In contrast, private passenger vehicles consumed 100% of total petrol consumed in this sector and only 11% of diesel. Freight transport alone consumedapproximately 52% of the total diesel consumed in the sector as freight activities are more energy intensive. Motorcycles are used considerably in Gandaki Province as well consuming 21% of the transportenergy. Private cars/jeep/van also consumed a large amount of energy (18%) in the Gandaki Province.

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

Sub-sector		Diesel	Gasoline	ATF	Electric	Total
Public Passenger	Bus	384.52	-	-	-	384.52
	Microbus	129.96	-	-	-	129.96
	Minibus	49.89	-	-	-	49.89
	Tempo	72.51	-	-	-	72.51
	E rickshaw	-	-	-	0.05	0.05
Total		**631.88**		**-**	**0.05**	**631.94**
Private Passenger	Car	127.98	213.58	-	-	341.55
	Jeep	43.87	114.75	-	-	158.62
	Van	19.07	30.91	-	-	49.98
	Motorcycle	-	665.94	-	-	665.94
Total		**190.92**	**1,025.18**	**-**	**-**	**1,216.09**
Freight	Truck	349.52	-	-	-	349.52
	Mini Truck	28.78	-	-	-	28.78
	Tractor	423.38	-	-	-	423.38
	Pickup	72.72	-	-	-	72.72
	Cargo van	1.07	-	-	-	1.07
Total		**875.47**	**-**	**-**	**-**	**875.47**
Aviation		-	-	435.12	-	**435.12**
Grand Total		**1,698.27**	**1025.18**	**435.12**	**0.05**	**3,158.61**[8]

(Survey 2022)

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

The transport sector is heavily dependent on imported petroleum products, so there is a huge prospect to switch to electric mobility. The use of e-rickshaw is getting popular, but the trend is not so as high as needed, 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.

6.7 Construction and Mining Sector

The construction and mining sector in Gandaki used the least amount of energy among the six sectors at 719 TJ. Among these, the highest amount of energy is used in the form of diesel – mostly for heavy equipment. Diesel is also used for thermalpurposes in addition to some LPG and nominal quantity of kerosene. LPG is also used by on-site workers for cooking and heating purposes of bitumen for mixing with asphalt. There may be an overlapping with energy consumption in the freight transport subsector as dumper trucks are widely used in the construction sector.

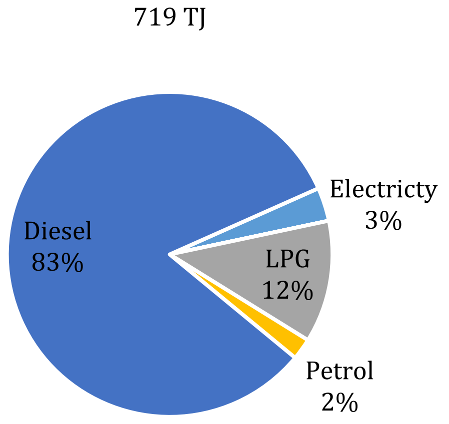


Figure 6-9. Energy Mix in Construction and Mining Sector

6.8 Fuel Demand by Time of Day

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

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

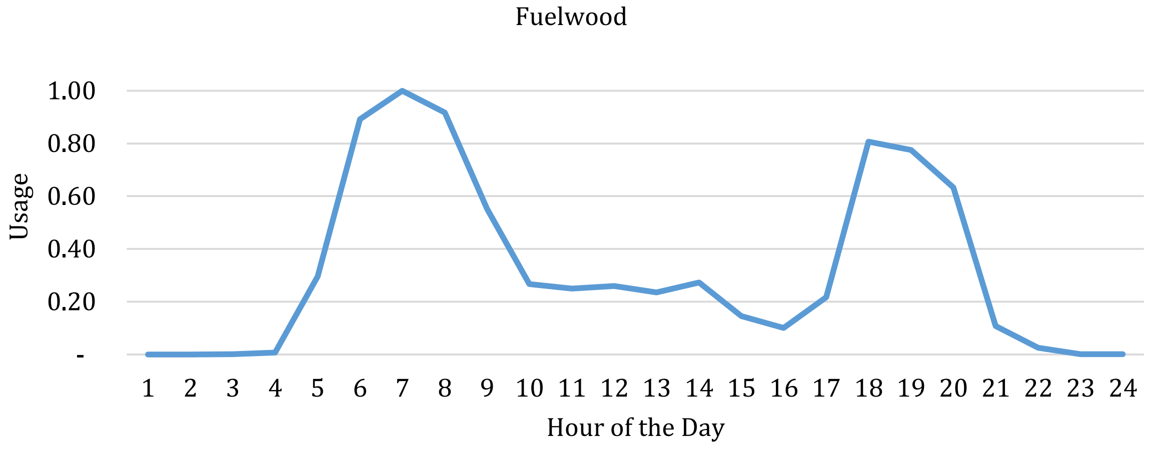


Figure 6-10. Energy Usage/Load Distribution Curve for Fuelwood in Residential Sector

It can be seen in **Figure 6-11** that the usage of LPG starts as early as 5 AM and peaks between 7AM 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 little later than for fuelwood as these being easy to use, as well as due to lifestyle habits.

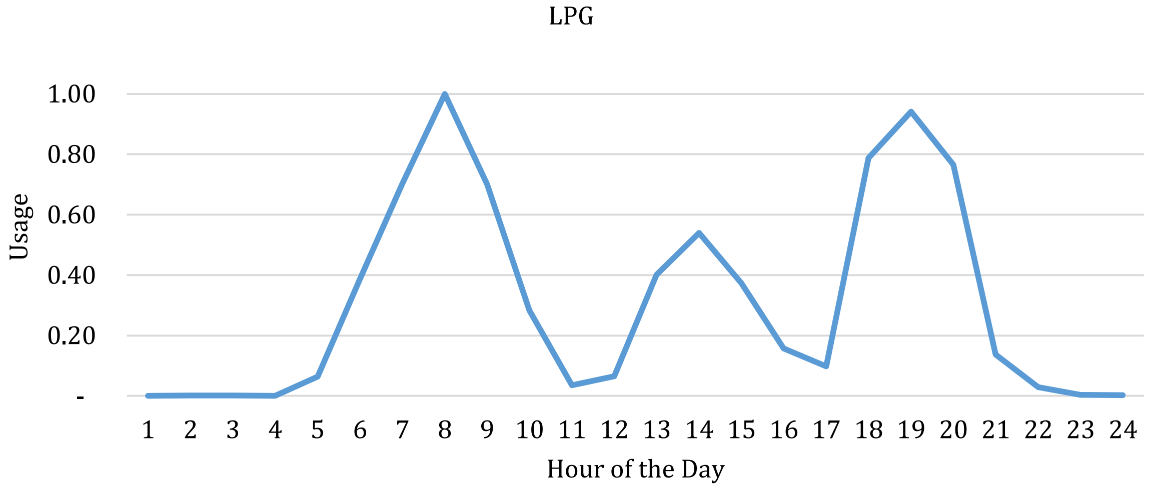


Figure 6-11. Energy Usage/Load Distribution Curve for LPG in Residential Sector

In the residential sector, it can be seen in **Figure 6-12** that the usage of electricity climbs as early as 4 AM and peaks between 6 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.

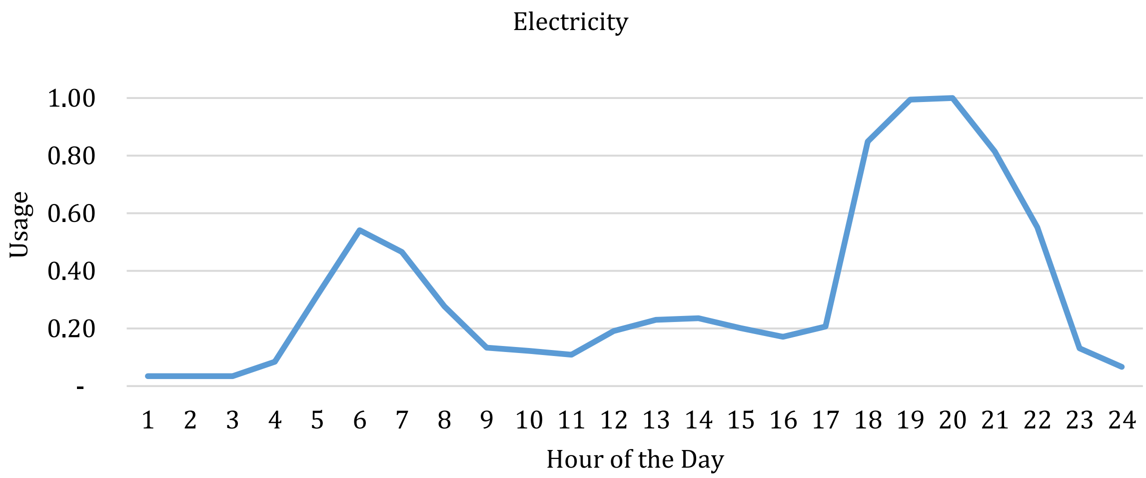


Figure 6-12. Energy Usage/Load Distribution Curve for Electricity in Residential Sector

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 to 8 AM. Its usage is low during daytime. 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.

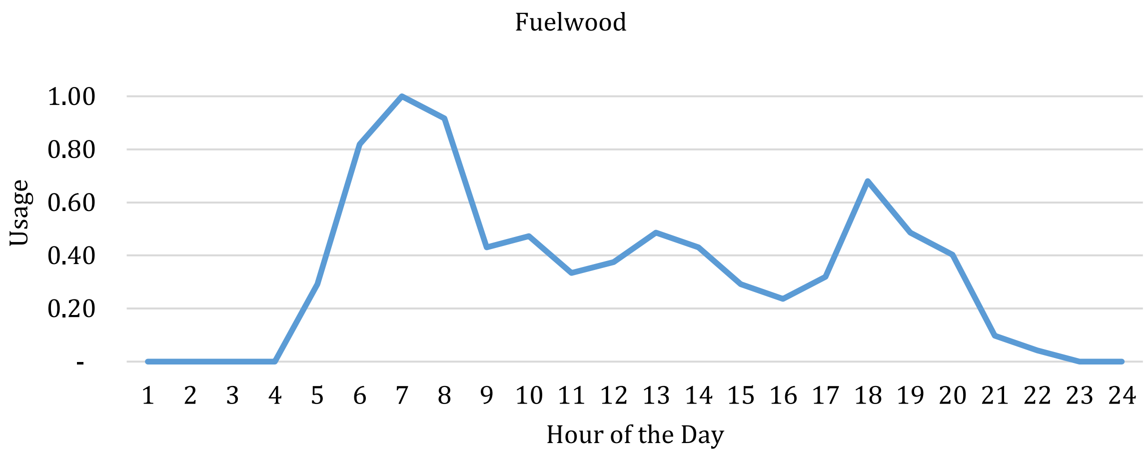


Figure 6-13. Energy Usage/Load Distribution Curve for Fuelwood in Commercial Sector

It can be seen in **Figure 6-14** that the usage of LPG peaks at three spots of daytime. The LPG usage starts at 5 AM and first peaks at 8AM. Its usage again peaks during daytime, corresponding to afternoon snacks between 2 PM to 3 PM. Finally, it again peaks between 6PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals at hotels, schools, hospitals. Like fuelwood, the usage of LPG remains high even in daytime, as these are constantly being used although the day.

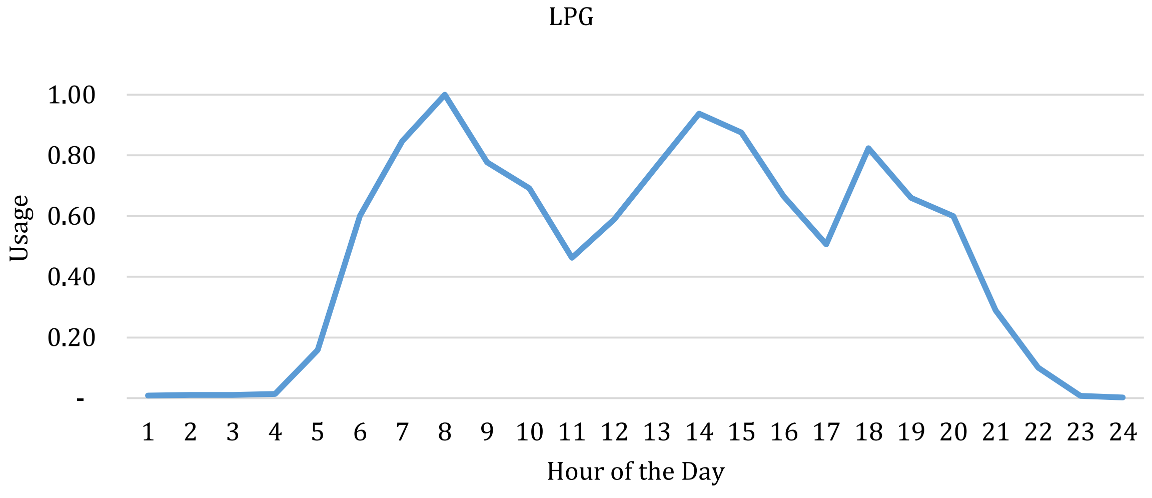


Figure 6-14. Energy Usage/Load Distribution Curve for LPG in Commercial Sector

The electricity uses in commercial sector starts at 5:00 AM, as seen from **Figure 6-15**, when the service activities slowly starts such as in schools or hospitals then it begins to rise up uh till the middle of the day when the activities are still going on including office activities and other commercial services. The major electricity uses peaks between 6:00 PM to 8:00 PM which is a highly active hour for services like hotels and restaurants, as well as shops and others in commercial sector.

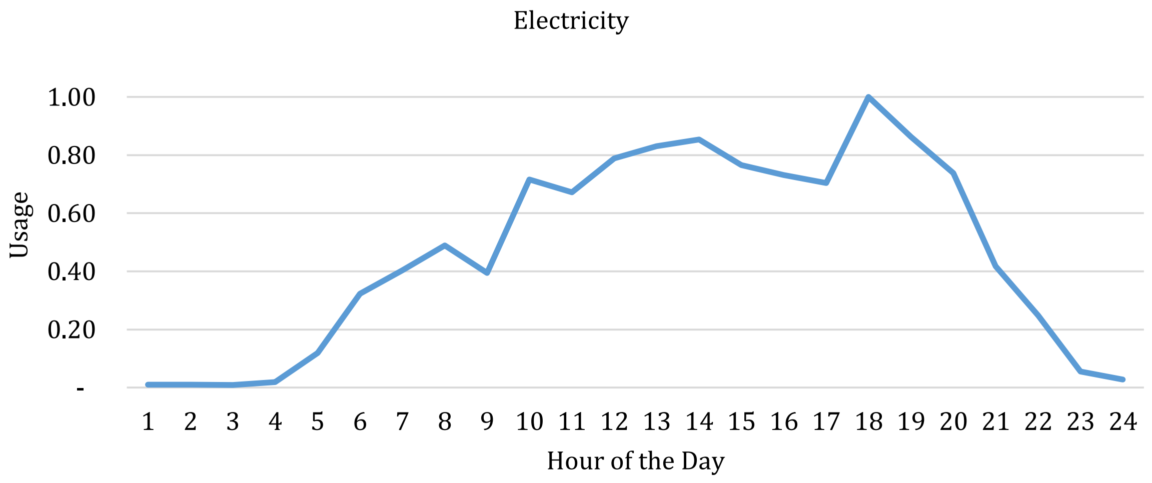
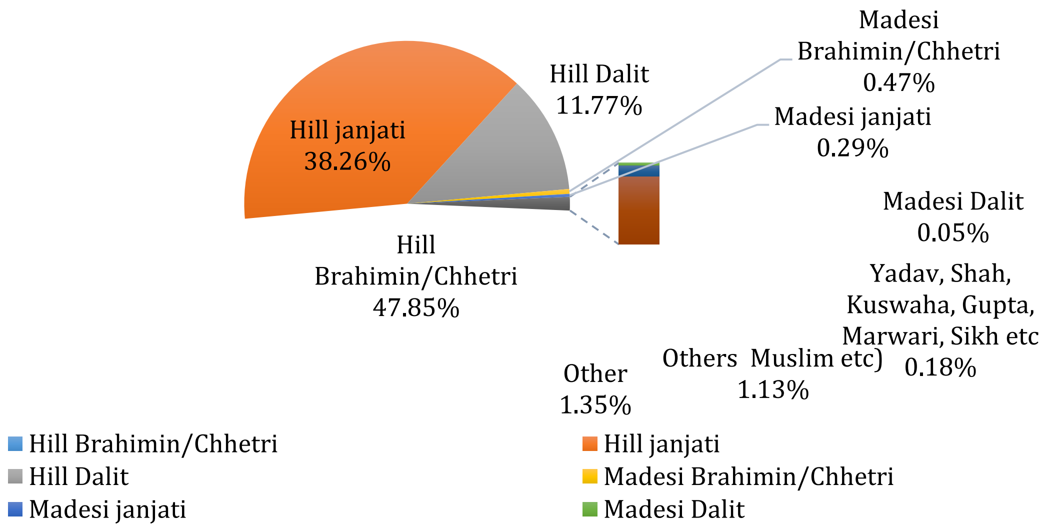


Figure 6-15. Energy Usage/Load Distribution Curve for Electricity in Commercial Sector

7. Socio-economic and Technical Analysis

7.1 Socio-Economic Status

Gandaki Province ranges from low Terai to Mountain regions. Due to this, there is a large variation in socio-economic characteristics. As shown in **Figure 7-1,**most of the respondents belong to the Mountain, Hill, and Terai regions. Large shares of respondents belong to Hill janjati in Mountain region and in Hill regions, Hill Brahim/Chhetriare in majority, whereas, in Terai region, Hill Brahmin/Chhetri, Hill Janjati, and Hill Dalit are the major ethnic groups. Overall, Hill Brahims/Chhetris are major respondents and are secondedby the Hill janjati in Gandkiprovince, However, the respondents also include other ethnic groups ranging to Hill Janajati and Hill Dalit groups as well.



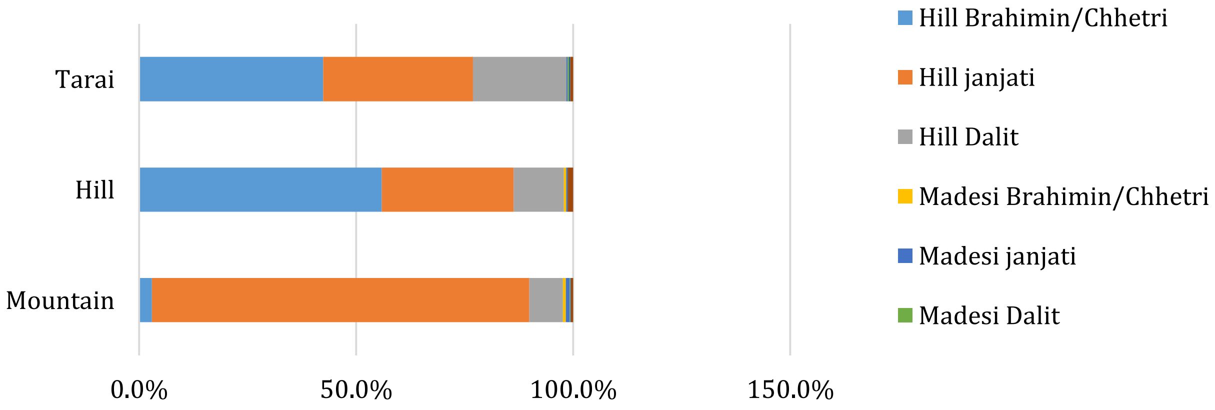


Figure 7-1: Mix of Respondents by Ethnic Group in Gandaki Province (top) and Ecological Regions (bottom)

Education level influences decision-making. Thus, looking at the education level of household heads in Gandaki Province, it was seen that substantial household heads have no formal education followed by partially literate. Nearly 45% of household heads do not have proper education **(Figure 7-2).**And the impact can be seen in the energy mix as well-fuelwood and other biomass are still being predominantly used. Ecologically, Terai region hasthe highest proportion of the population without formal education, and the education level seems higher in the Mountain region.

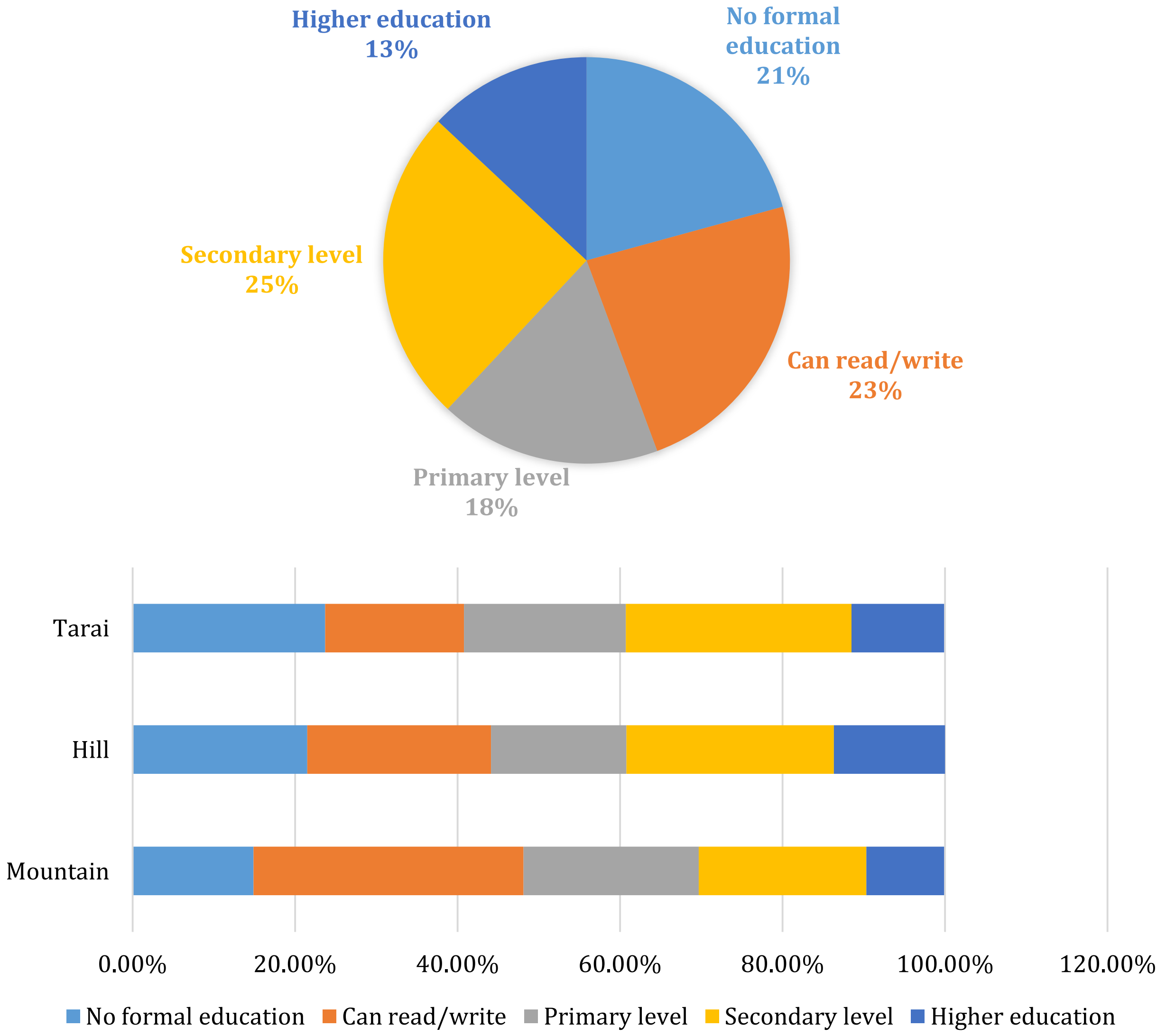


Figure 7-2: Mix of Respondents by Education Level of Household Head in Gandaki Province (top) and Ecological Regions (bottom)

Another important aspect of socioeconomic behavioris 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 isindependent 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 66% family has a major source of income in agriculture and in the terai region family business is prevalent as shown in **Figure 7-3.**

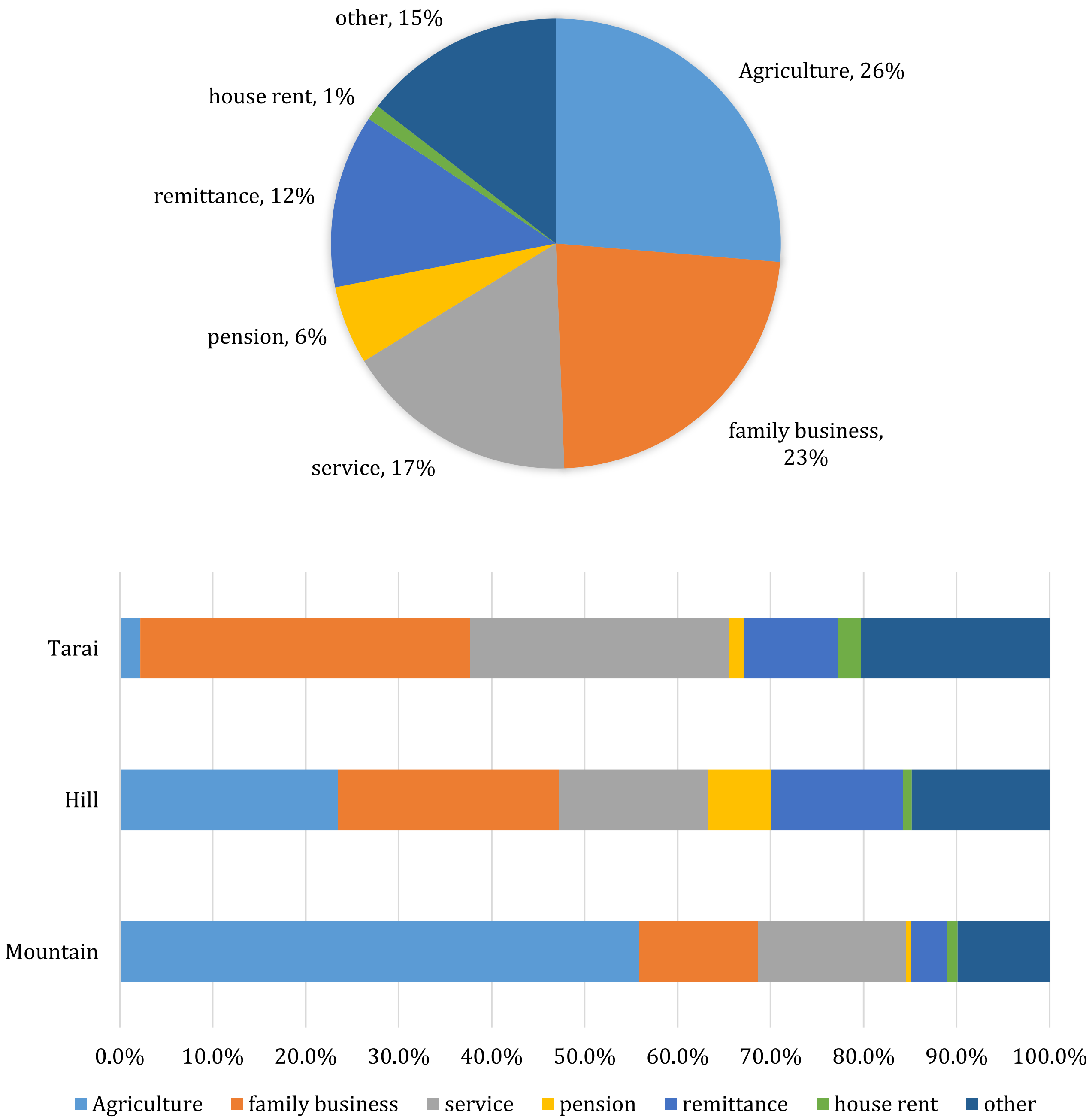


Figure 7-3: Mix of Respondents by Major Source of Income in Gandaki Province (top) and Ecological Regions (bottom)

NR390,000 annual income is the average income per household inGandaki Province as per the sample survey. This income level is near par with reference to the income level as perNational Living Standards survey Rs 30,121.00 per month (Fifth Household Budget Survey Nepal RastraBank 2014-2015). Comparing ecologically, the income level is higher on average in Terai. This is mostly due to higher economic activity in the terai region due to easyaccess to economic centresand the neighboring country. However, there is a hugevariance from the mean level of income in most of the cases which is evident from **Figure 7-4.**

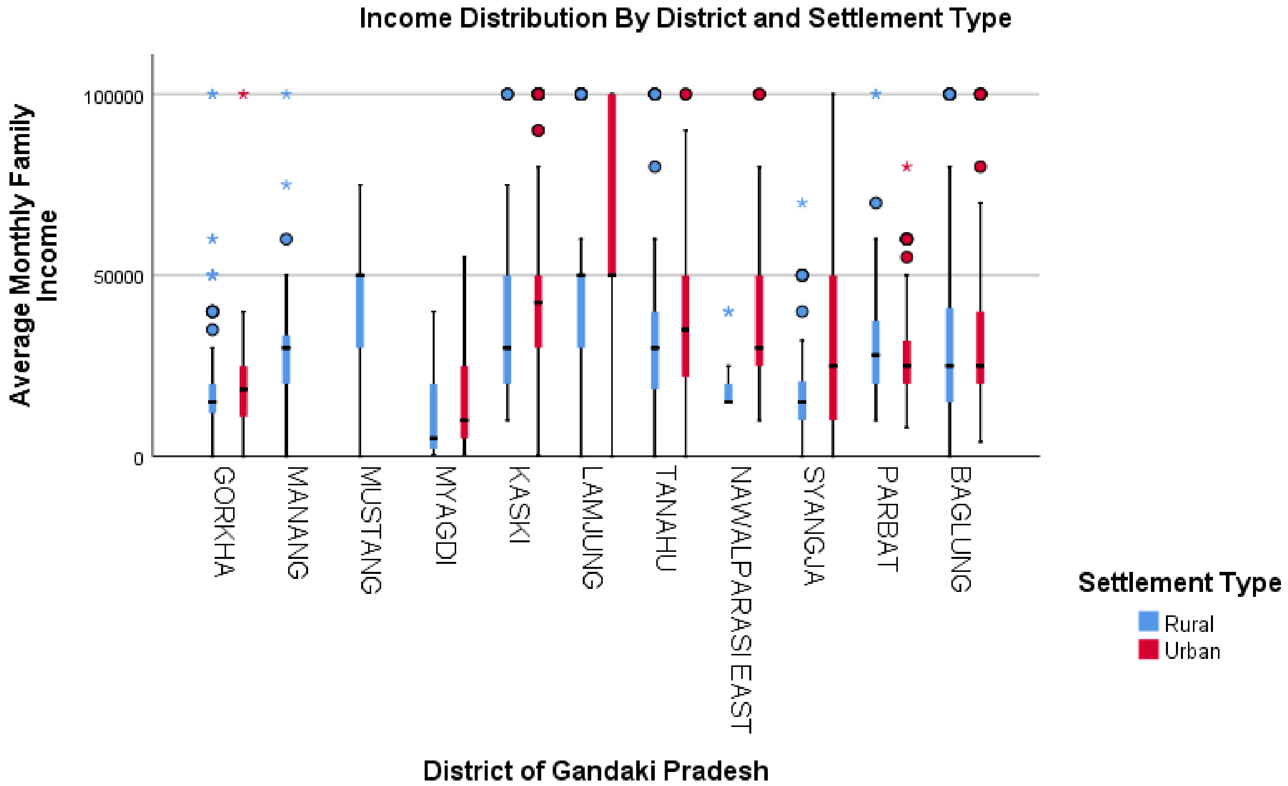


Figure 7-4: Average Monthly Income of Households in Gandaki Province

In Gandaki Province, more than 50% of the surveyed households found are made of mud mortar with brick or stone, followed by RCC frame with cement mortar, and the remaining are from bamboo or wood respectively **(Figure 7-5).** However, the share of RCC frames with cement mortar is seen to be in the increasing trend, especially after the earthquake in 2015.

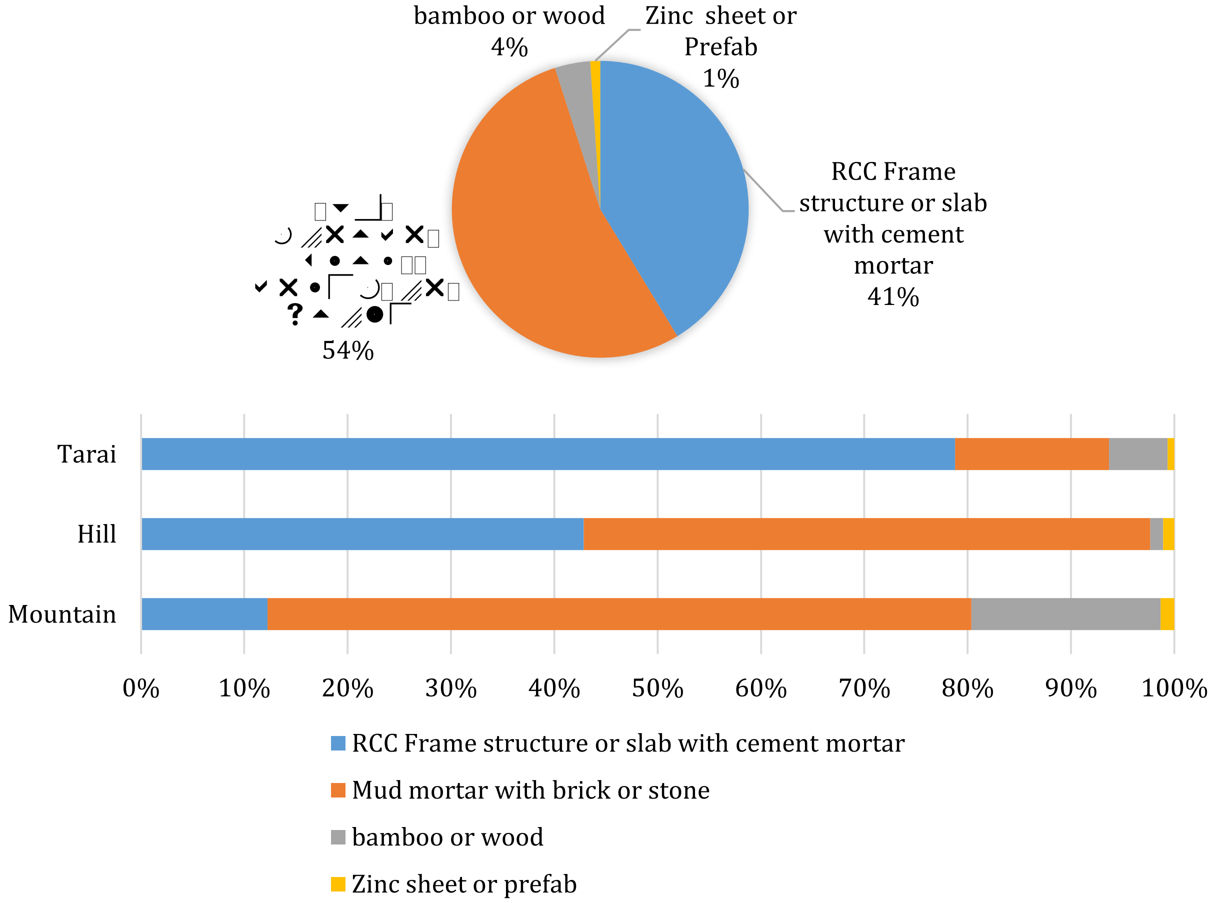


Figure 7-5: Mix of Respondent Household by Build Type in Gandaki Province (top) Ecological Regions (bottom)

Meanwhile, for the roof structure, 66% households still used galvanized iron sheets or tile, or slate followed by RCC **(Figure 7-6).**

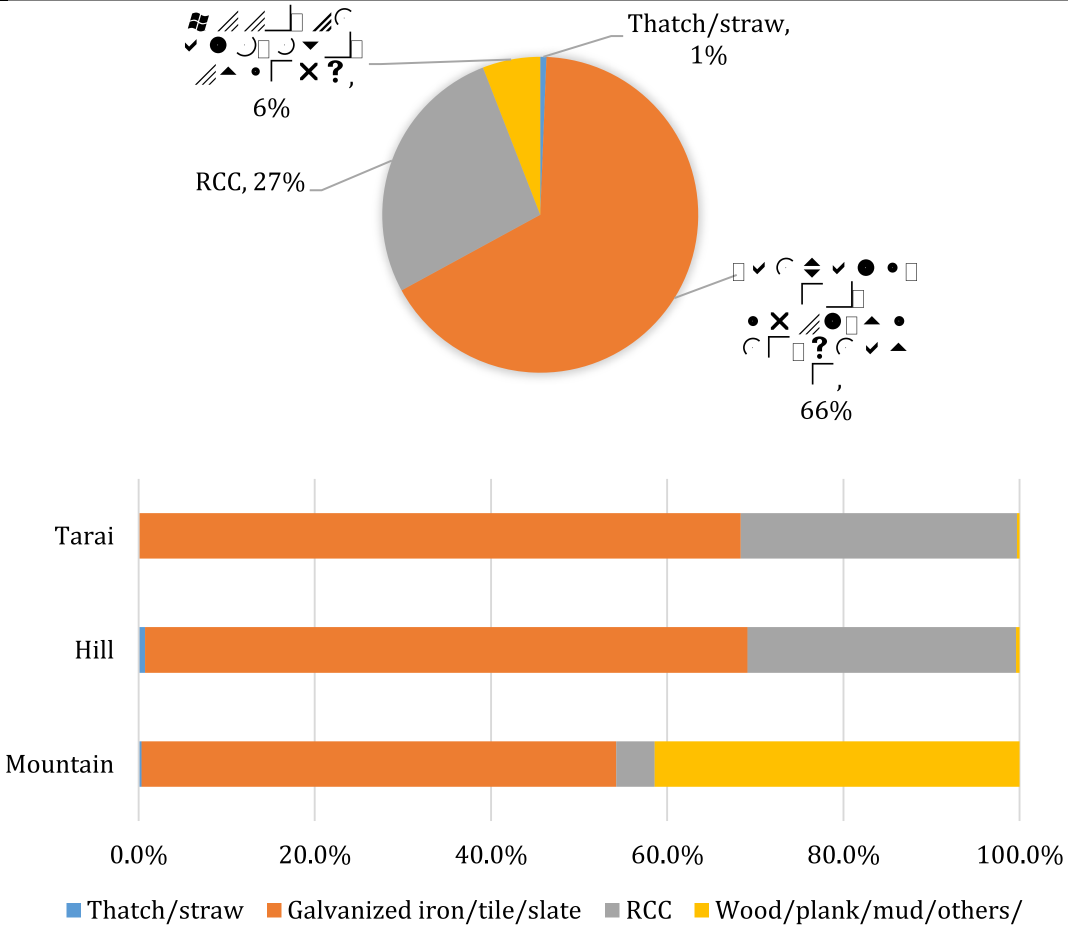


Figure 7-6: Mix of Respondent Households by Roof Type in Gandaki (top) and Ecological Regions (bottom)

7.2 Respondents by Gender

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

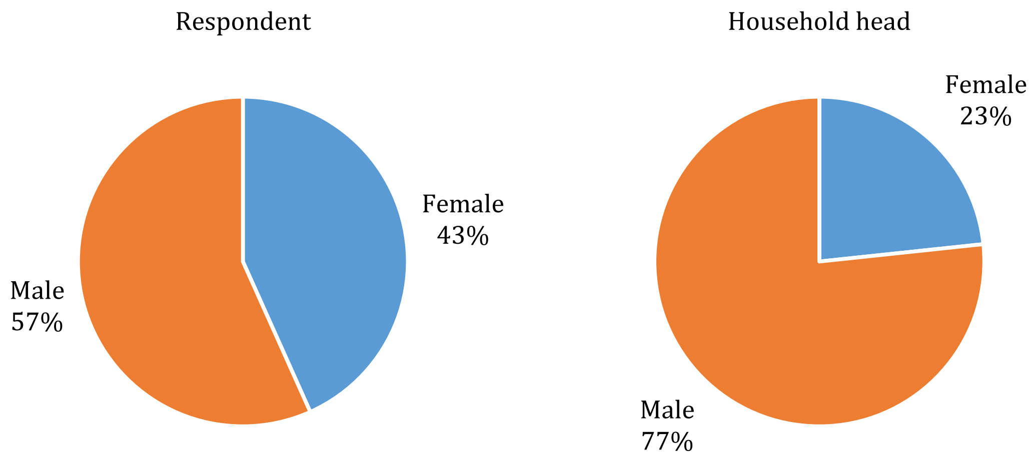
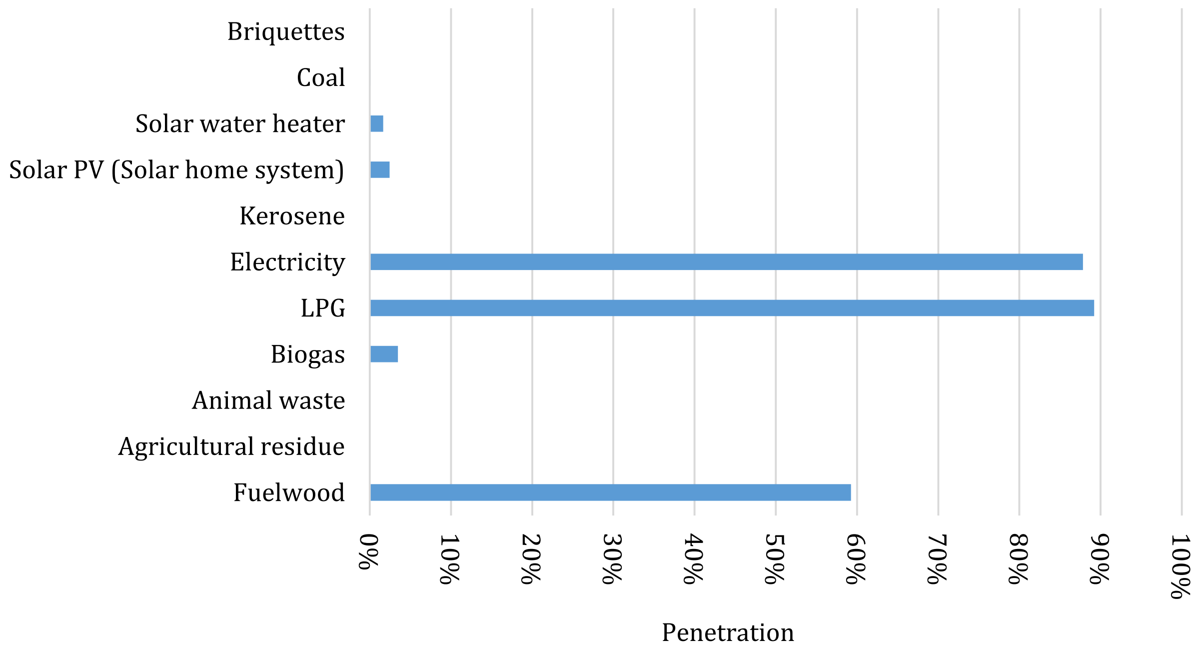


Figure 7-7: Mix of Household Respondents and the Household Head by Gender

7.3 Energy Access to Society

Figure 7-8shows the penetration of energy types in the Gandaki Province. Nearly 88% of the surveyed sample population has access to electricity at the household level. The use of fuelwood is nearly 60% of the respondents use it as a source of energy. The usage of LPG is at nearly 90%. This energy mix shows that the society in Gandaki Province is still inthe phase of energy transition from traditional to modern fuels. Firstly, traditional technology is very much energy inefficient and thus demands higher energy consumption and secondly, the traditional energy sources are usually taken as free of cost if the opportunity cost of fuelwood collection is not considered. Thus, people tend to use these sources more often. **Figure 7-8**also indicates the fuel stacking in Gandaki Province, 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.



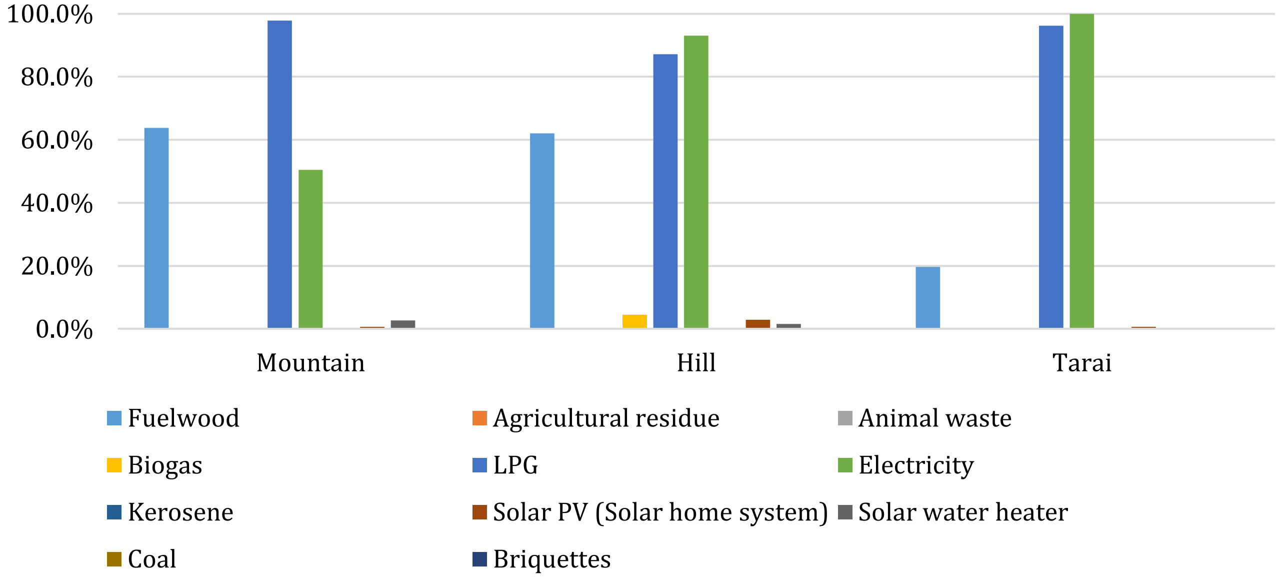


Figure 7-8: Penetration of Energy Types in Gandaki (top) and Ecological Regions(bottom)

Table 7-1shows how much people paid for commercially traded energy sources. At current times, even fuelwood is being traded at an average rate of NRs. 462 per bhari (around 40 kg) on average. Meanwhile, the LPG in Gandaki Province costs around NR 1,874 per cylinder, with transportation costs. It is seen that LPG is available at marked prices in Terai, however, due to transport costs, it is much higher in costs in hills and mountain regions. Thus, the upfront cost of commercial energy still seems high. If we consider energy efficiency, the cost of useful energy would be much lower for commercial energy.

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

Fuel type	Unit	Gandaki Province	Mountain	Hill	Terai
Fuelwood	40Kg	462		464	200
LPG	Cylinder	1,874.3	2,240.6	1,810.7	1,814.3
Coal	Kg	67		67	

	unit	Gorkha	Manang	Mustang	Myagdi	Kaski	Lamjung	Tanahun	Nawalpur	Syangja	Parbat	Baglung
Fuelwood	40Kg						298		200	281	230	577
LPG	Cylinder	1,821.4	2,388.8	2,027.3	1,830.7	1,666.4	1,789.6	1,801.1	1,814.3	1,858.4	1,755.8	1,944.1
Coal	Kg	67										

Figure 7-9shows the share of electricity connection as per ampere capacity of households who have electricity. It was observed in the survey that nearly 50% of the households lie within the minimal amperage capacity of 5A**.** For electric cooking, it is essential to have an electricity connection of at least 15 A.

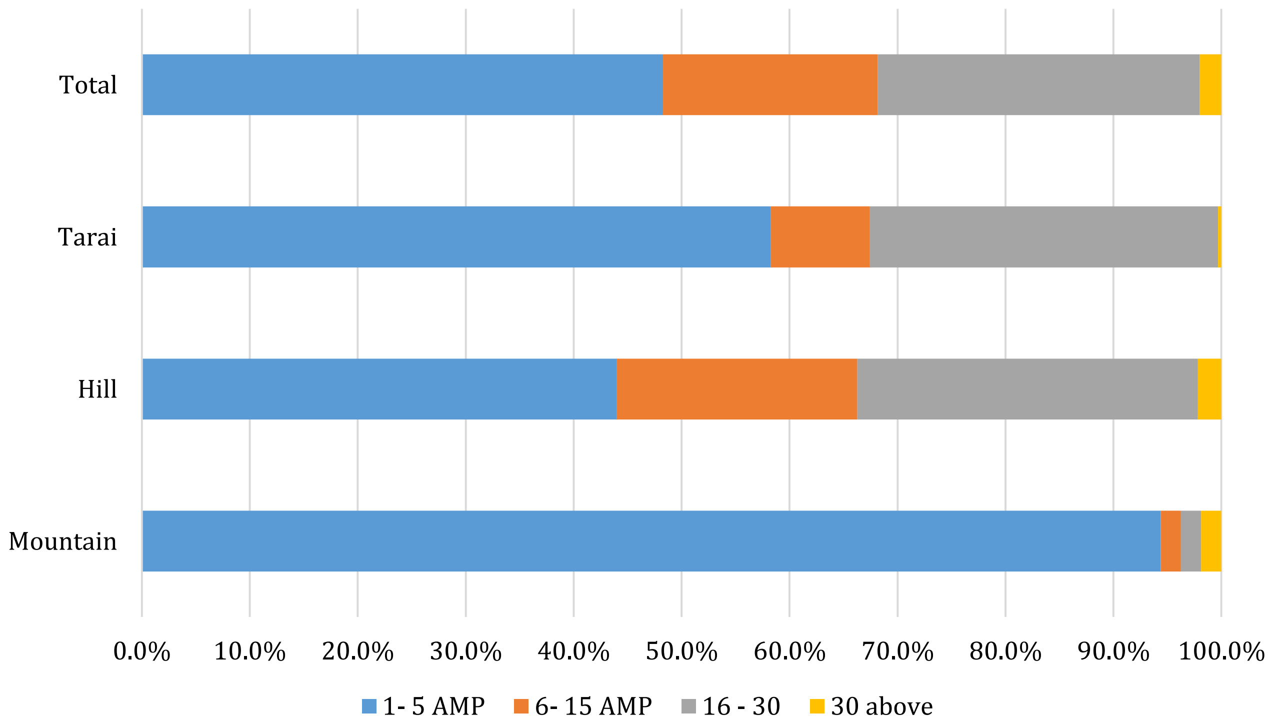


Figure 7-9: Mix of Ampere Capacity of Households with Electricity Access

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

8. Energy Scenario Analysis

8.1 Scenario Development

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

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

Further, thisIntegrated 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. Energy demand projections obtained from the MAED modeling framework are exogenously input in the IEEC model. 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.

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 shows the total energy demand for the low growth case of various fuel types from the base year to year 2050. The total energy demand in Gandaki Province is expected to grow from current level of 46 PJ in 2022 to 56 PJ in 2030 and 146 PJ in year 2050 i.e. the energy demand will triple in three decades, with an average annual growth rate of energy demand is 4.15% per annum. Meanwhile the per capita energy demand is expected to grow from 18.74 GJ in 2022 to 55 GJ in 2050 in this scenario which indicates that the energy consumption in future is going to increase more rapidly than the population growth, primarily in economic sectors.

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***	24.98	24.61	24.73	26.61	30.89	38.78	50.24
			Charcoal	0.05	0.05	0.06	0.08	0.11	0.15	0.21
		Modern biomass	**Biogas**	0.32	0.32	0.32	0.32	0.33	0.34	0.34
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		**Solar PV**	0.07	0.08	0.10	0.13	0.18	0.25	0.35
			Grid Electricity	2.27	3.29	4.02	5.07	6.58	8.80	12.11
Non-renewable			**Petrol**	1.69	1.70	1.78	2.15	2.65	3.38	4.49
			Diesel	10.47	12.87	16.68	22.17	30.08	41.71	59.10
			Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	2.28	2.59	3.42	4.61	6.34	8.87	12.66
			ATF**	0.44	0.44	0.44	0.45	0.46	0.46	0.47
			LPG	2.28	2.39	2.54	2.75	3.05	3.47	4.09
			Coal	1.61	1.61	1.62	1.63	1.83	1.86	1.61
Total				**46.46**	**49.96**	**55.74**	**65.99**	**82.49**	**108.08**	**145.96**

Figure 8-1 depicts the growth primary solid biomass fuels (PSF) (fuelwood, agri-residue and animal dung) can remain highin current years but will not continue to be the highest in future as the use of petroleum products will increase much higher and can surpass the demand of biomass after 2030. Whereas electricity demand would grow at 5% per annum, its demand for the total share will still be low. The share of electricity would increase by nearly 1.4 times in 2030 and four-fold in 2050.

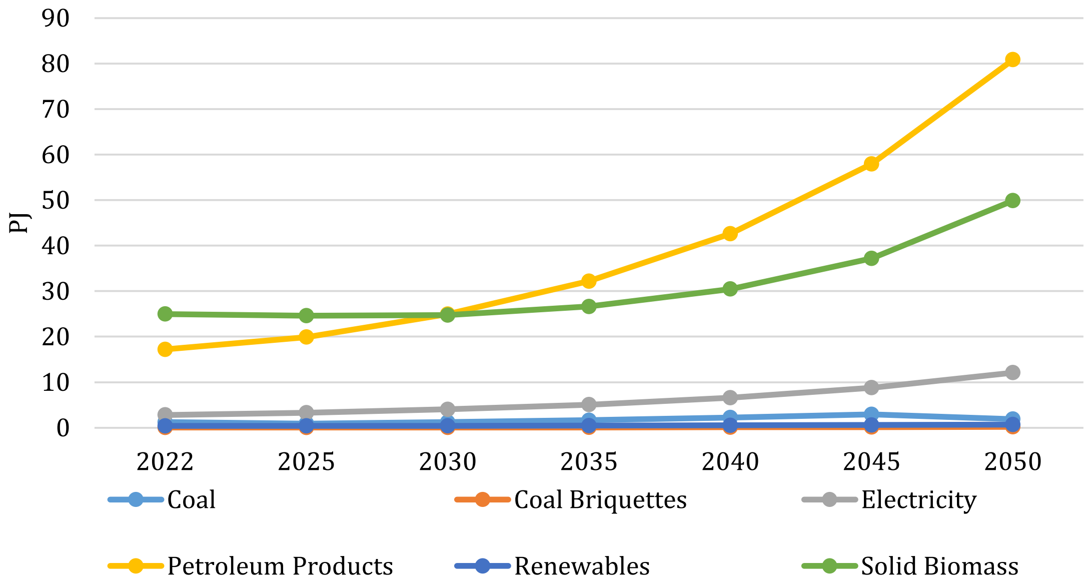
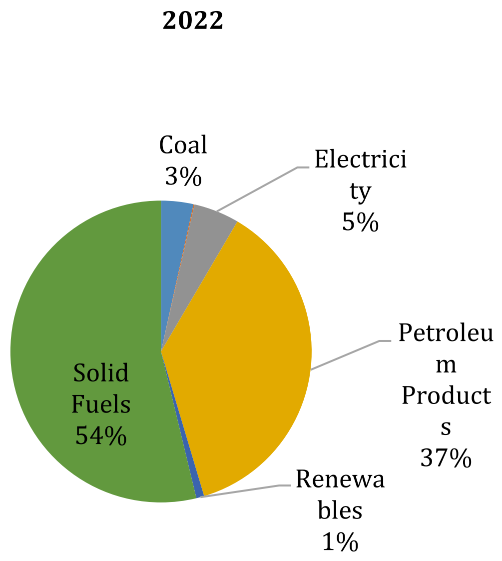
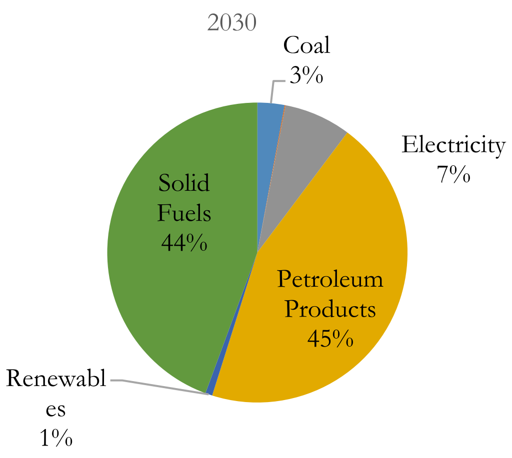


Figure 8-1. Fuel Demand Trend at Low Economic Growth Scenario

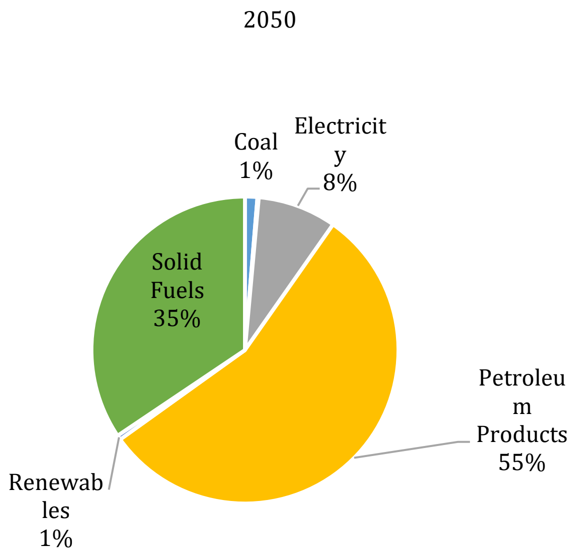
Figure 8-2 shows the energy mix in the total fuel demand which shows that demand forprimary solid biomass fuels (PSF)is expected to decrease to 45% in 2030 and 34% in the year 2050 respectively. Compared to 2022, the demand of petroleum products would grow by to 56% in 2050 while the electricity demand share would be 7% in 2030 and 8% in 2050 respectively, which signs that there will be need for some intervention for promotion of electrification and renewable energy.



Total Final Energy Demand = 46 PJ



(b) Total Final Energy Demand = 56 PJ



(c) Total Final Energy Demand = 146 PJ

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

Table 8-2 shows the sectoral energy demand in this scenario. The share of residential sector decreases to only 8% of the total final energy demand in 2050from 41% in 2022 due to shift to more efficient technologies. Meanwhile, the industrialsector's share of energy demand will increase to 50% in 2030 and 71% in 2050 because of increasing manufacturing activity but lack of proper energy efficiency interventions. Whereas the share of energy demands in the commercial sector will remain nearly stagnant till 2030. On the other hand, the share of demand in the transport sector will also fall, though the total energy demand increases. The falling shares in the commercial and transport sectors are not because of the fall in energy demand but the higher energy demand in the industrial sector. It is therefore crucial to put more focus on improving energy efficiency in the industrial sector.

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

	2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Agriculture	1.15	1.30	1.72	2.32	3.19	4.46	6.37
Commercial	4.06	4.30	4.95	5.95	7.43	9.58	12.74
Construction and Mining	0.72	0.82	1.08	1.45	2.00	2.80	3.99
Industry	18.04	21.95	28.45	37.81	51.93	73.21	103.73
Residential	19.34	18.23	16.00	14.42	13.25	12.34	11.97
Transport	3.16	3.36	3.53	4.03	4.70	5.69	7.17
Total	**46.46**	**49.96**	**55.74**	**65.99**	**82.49**	**108.08**	**145.96**

Figure 8-3 shows the power plant capacity required with 30% planning reserve on expected peak loadfor the study period. The required peak power plant capacity in 2022 was 160 MW. The future power capacity requirement would be nearly 515 MW in 2030 and 1,549 MW in 2050 to fulfill the demand of about 2,300 GWh and 6,800GWh respectively.

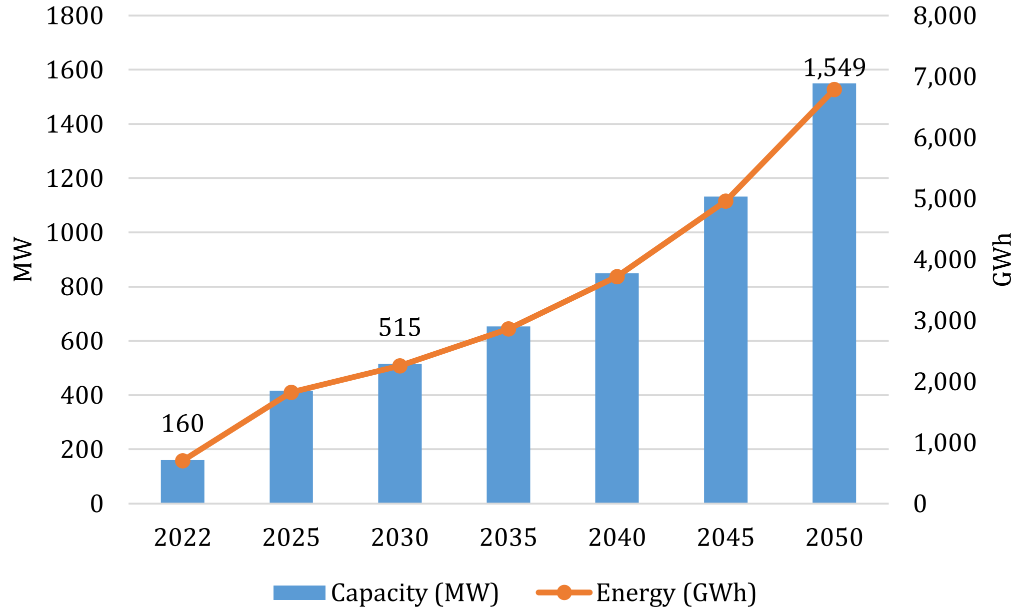


Figure 8-3. Installed Power Plant Capacity RequirementLow Economic Growth Scenario

GHG emissions trend in the Low Economic Growth Scenario is as shown in **Figure 8-4.** GHG emissions would increase from 1,500kt in 2022 to 2,100 kt in 2030 and will reach6,300kt in 2050. The GHG emissions would grow at an average growth rate of 5.2% during 2022-2050. There will be 4 times growth in GHG emissions in 2050 from its base year and it is mainly attributed to the demand in fossil fuels in the Gandaki Province.

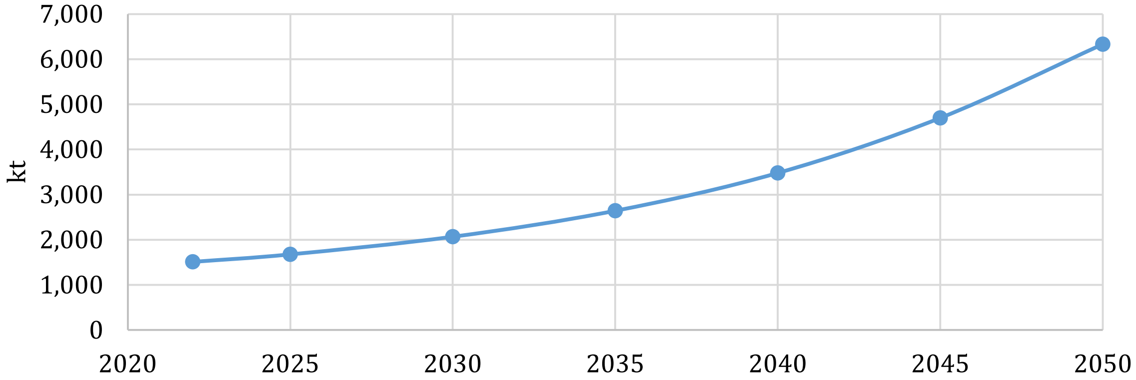


Figure 8-4. GHG Emissions at Low Economic Growth Scenario

- **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 nearly triple in 2050 with respect to current demand. Meanwhile, the share of renewables is also expected to increase slightly in years coming by, but on the other hand, the net import of petroleum fuelsis also seen to reach 57% in 2050 from 40% in 2022, all due to increase in carbon-based energy demand and the conventional demand technologies. The imported carbon-based fuels and their uses are also going to impact per capita GHG emissions reaching almost four times by 2050 from the current baseline values. **Table 8-3**shows growing dependence of the economy on imported fossil fuels if no policy intervention is implemented.

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

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	18.74	20.00	22.03	25.76	31.80	41.15	54.89
Final electricity demand	kWh/capita	262	375	453	565	724	957	1,302
Final energy demand	GJ/million NRS	124	118	99	87	79	74	70
Final Electricity Demand	kWh/million NRS	1,739	2,203	2,044	1,914	1,810	1,730	1,670
Total Electricity Used/household	kWh/HH	410	410	410	410	410	410	410
Share of modern renewable energy in final total energy demand	per cent	5.73%	7.39%	7.98%	8.38%	8.60%	8.68%	8.77%
The ratio of net import to total primary energy supply	per cent	40.38 %	43.25 %	47.55 %	51.17 %	53.82 %	55.30 %	56.67 %
GHG emissions	GHG in Kg/capita	610	670	817	1,032	1,327	1,732	2,382

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 8-4shows 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 Gandaki Province is expected to grow from the current level of 46 PJ in 2022 to 58 PJ in 2030 and 237 PJ in the year 2050 which showsan increase of more than 5 folds. The average annual growth rate of energy demand is 6% for the HIH case which is higher than the LOW scenario case because of higher economic activities 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***	24.98	24.80	25.56	28.90	36.59	51.95	79.20
			Charcoal	0.05	0.05	0.06	0.09	0.13	0.18	0.21
		Modern biomass	**Biogas**	0.32	0.32	0.32	0.32	0.33	0.34	0.34
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		**Solar PV**	0.07	0.08	0.11	0.15	0.23	0.36	0.60
			Grid Electricity	2.27	3.34	4.23	5.67	8.06	12.21	19.75
Non-renewable			**Petrol**	1.69	1.70	1.85	2.35	3.14	4.52	7.04
			Diesel	10.47	13.10	17.78	25.32	37.89	59.73	99.46
			Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	2.28	2.64	3.66	5.30	8.04	12.80	21.46
			ATF**	0.44	0.44	0.44	0.45	0.46	0.46	0.47
			LPG	2.28	2.39	2.58	2.86	3.32	4.09	5.47
			Coal	1.61	1.67	1.77	1.87	2.22	2.72	3.22
Total				**46.46**	**50.54**	**58.36**	**73.30**	**100.40**	**149.36**	**237.23**

The share of primary solid biomass (fuelwood, agri-residue and animal dung) is high throughout the period and growing at an annual rate of 4%. Petroleum and coal demand are expected to grow at the rate of 7.6% and 3.5% respectively whereas electricity demand would grow at 7.2% per annum **Figure 8-5.** Thus, in HIH scenario too, the demand for petroleum products will surpass the demand for solid biomass, but ata higher rate than Low Economic Growth (LOW) scenario.

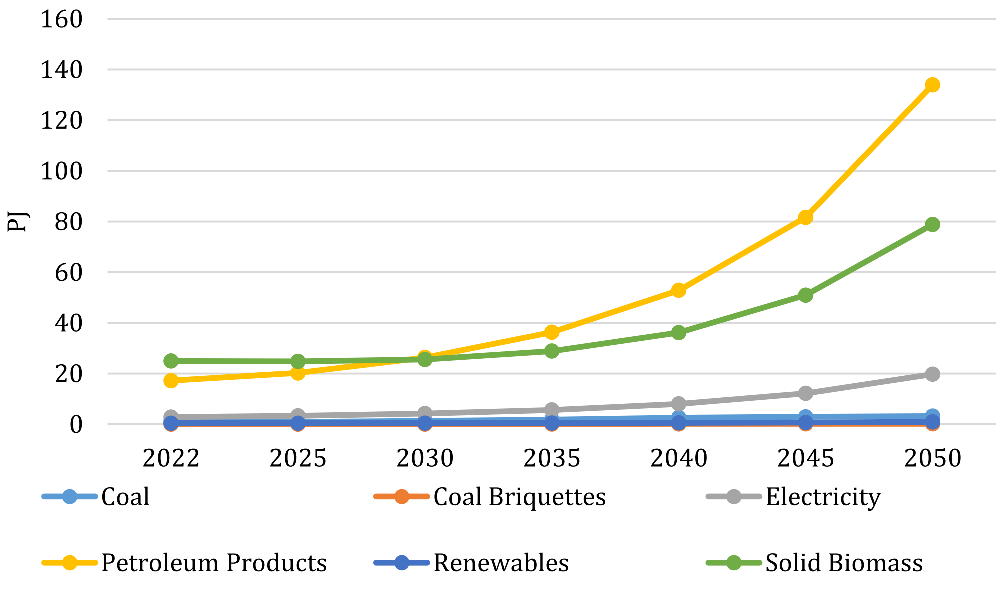
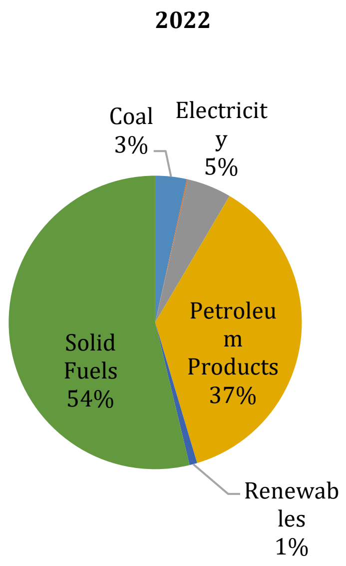
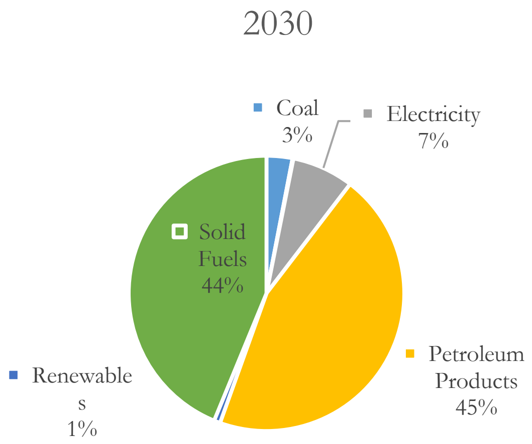


Figure 8-5. Fuel Demand Trend at High Economic Growth Scenario

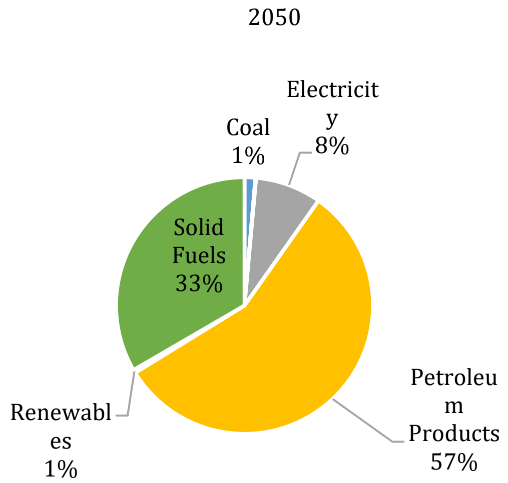
Figure 8-6 shows the energy mix in the total fuel demand for 2022, 2030 and 2050 years. The demand of solid biomass is expected to decrease to 44% in 2030 and 33% in the year 2050 respectively. Compared to 2022, the share in demand of petroleum products would grow to57% in 2050. The electricity demand share would be 7% in 2030 and 8% in 2050 respectively.



(a) Total Final Energy Demand = 46 PJ



(b) Total Final Energy Demand = 58 PJ



(c) Total Final Energy Demand = 237 PJ

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

Table 8-5 shows the sectoral energy demands in this scenario. The share of residential sector decreases to 5% in 2050 from 42% in 2022. Meanwhile, the industrialsector's share of energy demand will increase to 52% in 2030 and 74% in 2050. Whereas the share of energy demands in the commercial sector will increase to 9% in 2050. There will be a 4.4% growth of energy demand in the transport sector.

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

	2022	2025	2030	2035	2040	2045	2050
Agriculture	1.15	1.33	1.84	2.67	4.04	6.44	10.80
Commercial	4.06	4.38	5.27	6.80	9.35	13.69	21.34
Construction and Mining	0.72	0.83	1.15	1.67	2.53	4.03	6.76
Industry	18.04	22.40	30.47	43.44	65.87	105.67	175.83
Residential	19.34	18.23	16.00	14.42	13.25	12.34	11.97
Transport	3.16	3.36	3.62	4.29	5.35	7.19	10.53
Total	**46.46**	**50.53**	**58.36**	**73.30**	**100.40**	**149.36**	**237.23**

Figure 8-7 shows the power plant capacity required for the study period. The future power plant to be installed, including 30% planning reserved margin, would be 540 MW in 2030 and 2,500 MW in 2050 from the current demand of 160 MW. The electricity demand will grow at the rate of 11% with higher economic activities happening.

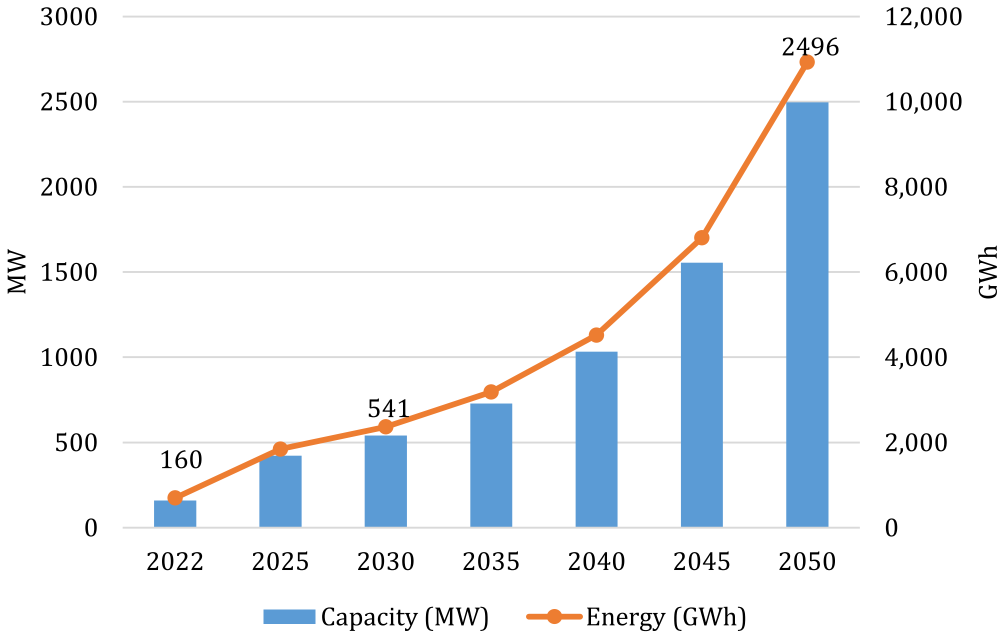


Figure 8-7. Installed Power Plant Capacity RequirementHigh Economic Growth Scenario

GHG emissions trend in High Economic Growth Scenario is as shown in **Figure 8-8.** GHG emissions would increase to 2,200 kt in 2030 and can reach 10,500kt in 2050. The GHG emissions would grow at an average growth rate of 7% during 2022-2050, reaching7 times the current GHG emissions in 2050. This increase is mainly attributed to the high demand for fossil fuels in the Gandaki Province.

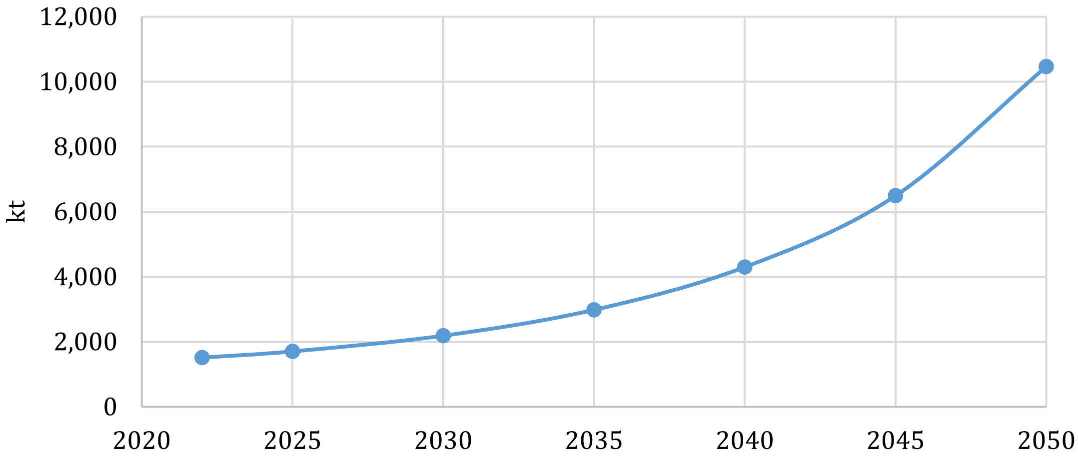


Figure 8-8. GHG Emissions at High Economic Growth Scenario

- **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 5 times in 2050 with respect to current demand. Meanwhile, the share of renewables is also expected to increase slightly in years coming by, but in the other hand the net import of fuel in also seen to reach 58% in 2050 from 40% 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 six 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	18.74	20.23	23.07	28.61	38.71	56.87	89.21
Final electricity demand	kWh/capita	262	380	476	631	888	1,330	2,126
Final energy demand	GJ/million NRS	124	119	104	97	97	103	114
Final Electricity Demand	kWh/million NRS	1,739	2,191	2,010	1,863	1,749	1,666	1,609
Total Electricity Used/household	kWh/HH	410	410	410	410	410	410	410
Share of renewable energy in final total energy demand	per cent	5.73%	7.40%	7.98%	8.39%	8.59%	8.64%	8.72%
The ratio of net import to total primary energy supply	per cent	40.38%	43.44%	48.12%	52.06%	54.84%	56.45%	57.80%
GHG emission	GHG in Kg/capita	610	680	863	1,163	1,642	2,436	3,936

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 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 Gandaki Province is expected to grow from the current level of 46 PJ in 2022 to 56 PJ in 2030 and 177 PJ in 2050 which accounts for three folds of increase. The average annual growth rate of energy demand is 4.9% for the reference case where the highest growing fuels are petroleum products.

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*	24.98	24.64	24.88	27.10	32.42	42.88	60.23
			Charcoal	0.05	0.05	0.06	0.08	0.11	0.17	0.21
		Modern biomass	Biogas	0.32	0.32	0.32	0.32	0.33	0.34	0.34
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.07	0.08	0.10	0.14	0.19	0.28	0.44
			Grid Electricity	2.27	3.30	4.06	5.20	6.98	9.86	14.74
Non-renewable			Petrol	1.69	1.70	1.79	2.19	2.78	3.73	5.37
			Diesel	10.47	12.91	16.87	22.84	32.16	47.33	73.02
			Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	2.28	2.60	3.46	4.76	6.79	10.09	15.69
			ATF**	0.44	0.44	0.44	0.45	0.46	0.46	0.47
			LPG	2.28	2.39	2.55	2.78	3.12	3.66	4.57
			Coal	1.61	1.63	1.65	1.68	1.92	2.14	2.36
Total				**46.46**	50.07	56.20	67.55	87.26	120.96	177.44

The share of primary solid biomass (fuelwood, agri- residue and animal dung) will not remain high throughout the period but will be surpassed by highly growing petroleum products which are expected to grow at the rate of 7.6% whereas electricity demand would grow at 7% per annum **Figure 8-9.** The share of electricity will remain below double digits in absence of interventions.

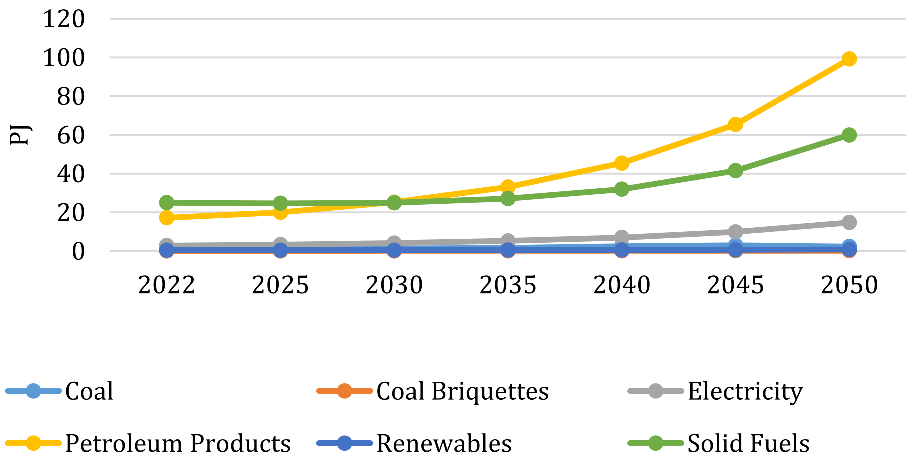
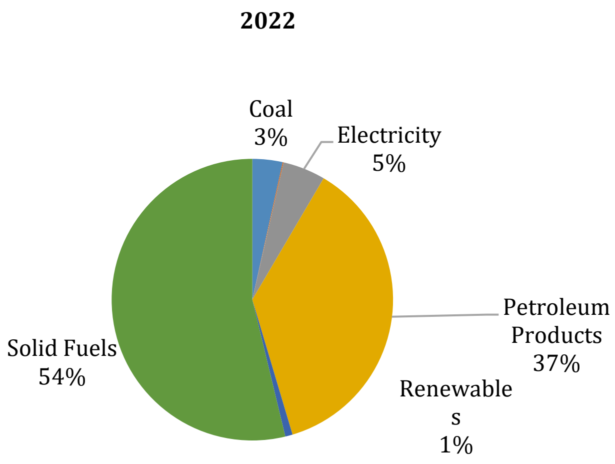
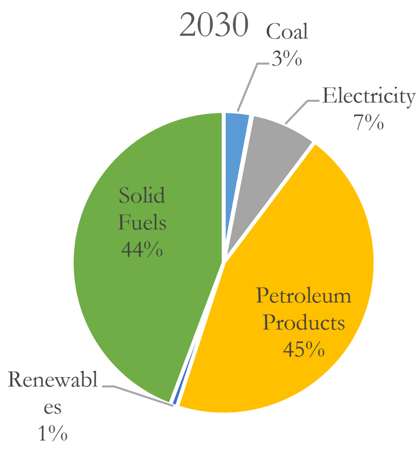


Figure 8-9. Fuel Demand Trend at Reference Economic Growth Scenario

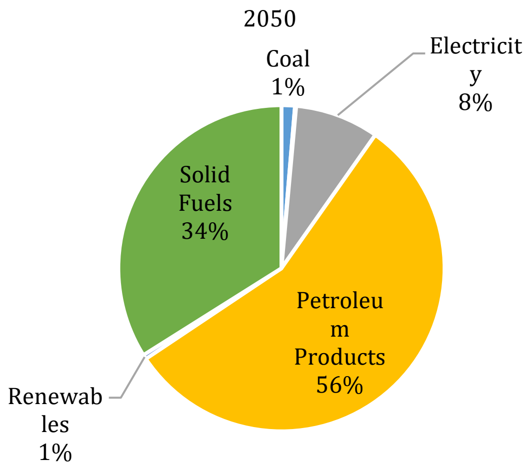
Figure 8-10shows the energy mix in the total fuel demand for 2022, 2030 and 2050 years. The demand of solid biomass is expected to decrease to 44% in 2030 and 35% in 2050 respectively. Compared to 2022, the demand of petroleum products would reach 56%. The electricity demand share would be 7% in 2030 and 8% in 2050 respectively.



(a) Total Final Energy Demand = 46 PJ



(b) Total Final Energy Demand = 56 PJ



(c) Total Final Energy Demand = 178 PJ

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

Table 8-8 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 6.7% in 2050 from 42% in 2022. Meanwhile, the industrialsector's share of energy demand will increase to 51% in 2030 and 73% in 2050. Whereas the share of Energy demands in the commercial sector will increase to 9% from its base year value of 8.7%. Although there will be an overall increase in energy demand, the share of energy demand in the transport sector will decrease, while the actual demand reaching nearly 3 folds in 2050 with respect to 2022.

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

	2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Agriculture	1.15	1.31	1.74	2.40	3.42	5.08	7.90
Commercial	4.06	4.32	5.00	6.13	7.94	10.87	15.70
Construction and Mining	0.72	0.82	1.09	1.50	2.14	3.18	4.95
Industry	18.04	22.03	28.81	39.01	55.64	83.34	128.60
Residential	19.34	18.23	16.00	14.42	13.25	12.34	11.97
Transport	3.16	3.36	3.55	4.08	4.87	6.16	8.33
Total	**46.46**	**50.06**	**56.20**	**67.55**	**87.26**	**120.96**	**177.44**

As depicted in **Figure 8-11,** the projected energy scenario for Gandaki Province in 2050, in lack of proactive policies promoting clean and renewable energy, reveals a persistent dependence on biomass and an escalating reliance on imported petroleum products. This trajectory anticipates a substantial upswing in fossil fuel demand, raising questions about the sustainability of extensive biomass extraction from the region's forests. Moreover, the economic feasibility of sustaining the prolonged importation of substantial fossil fuel quantities poses a valid concern. The illustration underscores the pressing need for strategic interventions to steer the province towards a more sustainable and resilient energy future.

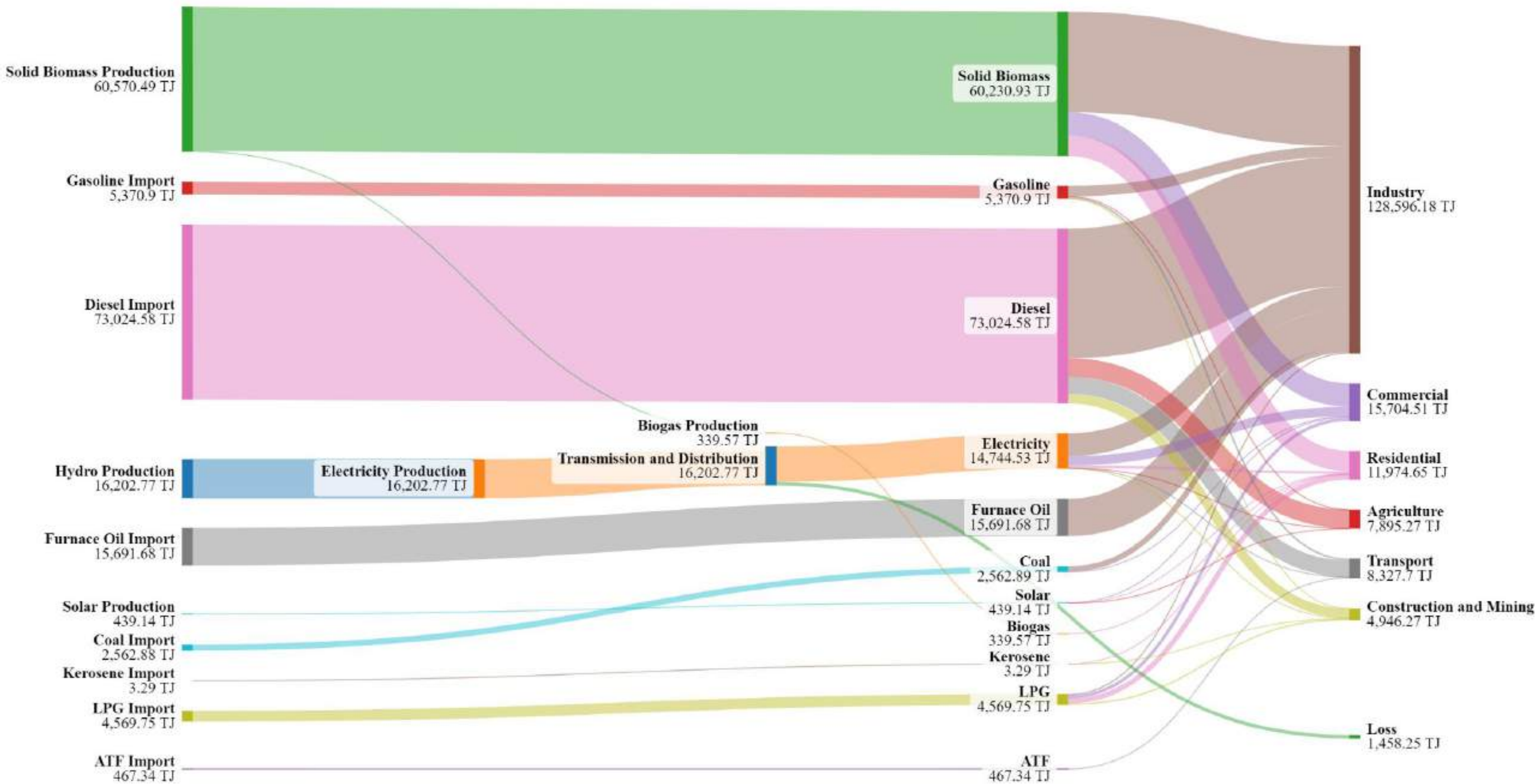


Figure 8-11. Sankey Diagram for Flow of Energy in 2050 in the Reference Scenario

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

Figure 8-12shows the power plant capacity required for the study period, with 30% reserve margin on peak demand. The future power requirement would be 520 MW in 2030 and 1,876MW in 2050. The electricity demand will be 2,300 GWh in 2030 and 8,300 GWh in 2050.

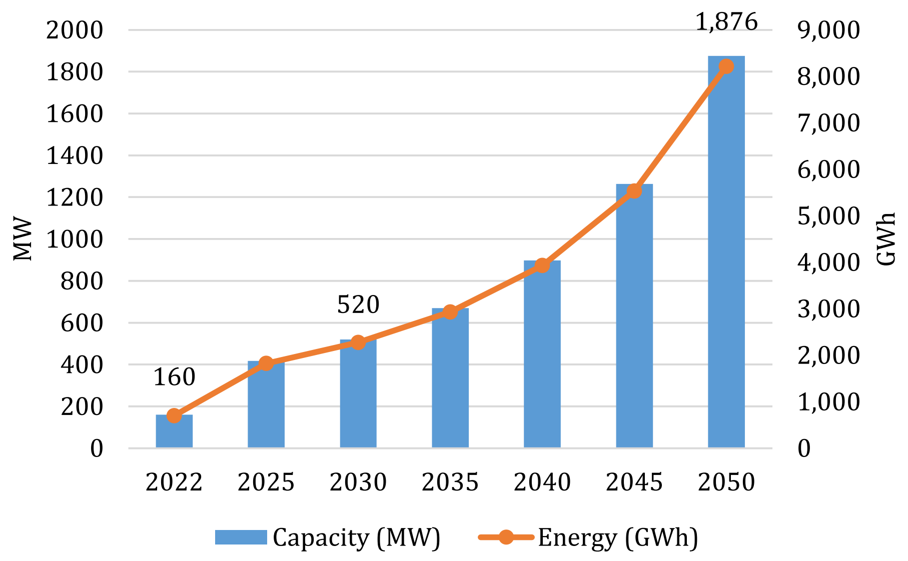


Figure 8-12. Installed Power Plant Capacity requirement at Reference Economic Growth Scenario

GHG emissions trend in Reference Economic Growth Scenario is as shown in **Figure 8-13.** GHG emissions would increase from 1,500kt in 2022 to 2,100kt in 2030 and will reach7,800kt in 2050. The GHG emissions would grow at an average growth rate of 5% during 2022-2050. There will be 5 times growth in GHG emissions in 2050 from its base year and it is mainly attributed to the high demand in fossil fuels in the Gandaki Province.

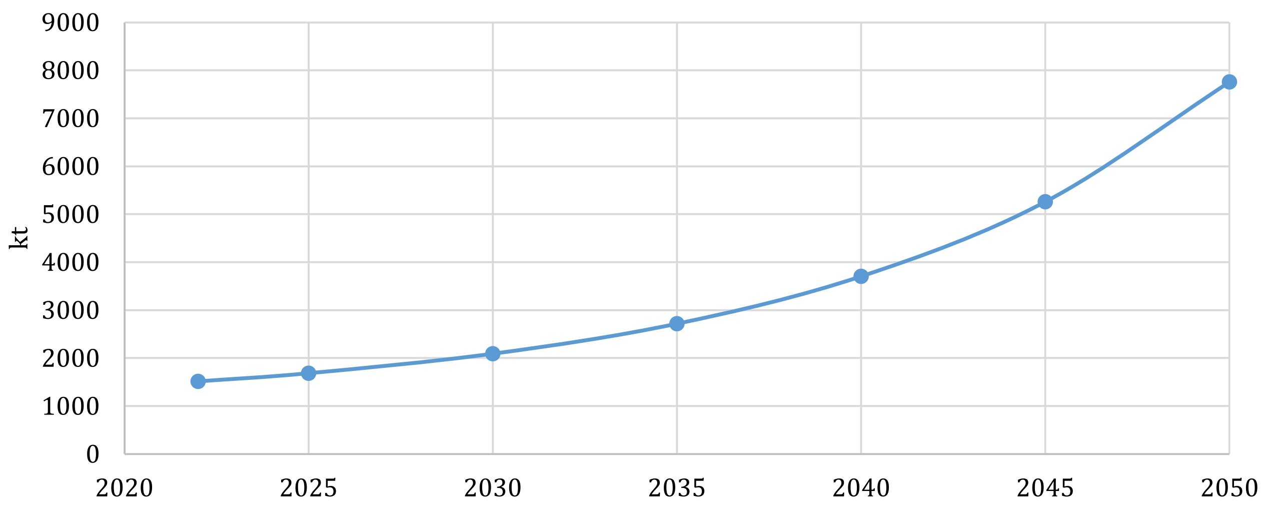


Figure 8-13. GHG emissions at Reference Economic Growth Scenario

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

Table 8-9 gives the energy indicators for Reference Economic Growth Scenario which shows that under normal circumstances, with no policy intervention in energy sector, the energy demand would increase such that per capita energy demand would more than triple in 2050 with respect to current demand. Meanwhile, the share of renewables is also expected to increase slightly in years coming by, but in the other hand the net import of fuel in also seen to reach 57% in 2050 from 40% in 2022, all due to increase in carbon-based energy demand and the conventional demand technologies. The imported carbon-based fuels and their uses are also going to impact per capita GHG emissions reaching almost five times by 2050 from the current baseline values.

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

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	18.74	20.04	22.21	26.37	33.64	46.06	66.73
Final electricity demand	kWh/capita	262	376	457	579	768	1,073	1,586
Final energy demand	GJ/million NRS	124	118	100	89	84	83	86
Final Electricity Demand	kWh/million NRS	1,739	2,201	2,038	1,902	1,791	1,705	1,641
Total Electricity Used/household	kWh/HH	410	410	410	410	410	410	410
Share of renewable energy in final total energy demand	per cent	5.73%	7.39%	7.98%	8.38%	8.60%	8.67%	8.75%
the ratio of net import to total primary energy supply	per cent	40.38 %	43.29 %	47.66 %	51.38 %	54.13 %	55.74 %	57.19 %
GHG emission	GHG in Kg/capita	610	672	825	1,060	1,411	1,952	2,918

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.
- 50% electrification in farm machineries by 2050

Commercial sector

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

Transportation

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

Industry:

- Boiler
  - 50% electric boiler
- Motive power and other
  - 100% electrification by 2050
- Process Heat
  - 30% electrification, 70% alternative fuels by 2050. Solid biomass fuels are profusely used in industry - especially in the food and beverage industrial sub-sector. Since they are considered carbon-neutral and there are suggestions that solid biomass is to be used also as it isdomestically available.

Residential sector:

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

The final demands of various fuels in this scenario are given in **Table 8-10.** The total energy demand in 2030 and 2050 is expected to be 48 PJ and 168 PJ respectively. Per capita energy demand is expected to be 63 GJ in 2050 in the Sustainable Energy Development Scenario (SEDS), whereas it would be 67 GJ in the Reference Economic Growth Scenario.

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

SEDS				2022	2025	2030	2035	2040	2045	2050
Renewables	**Conventional renewable**	**Traditional biomass**	**PSF***	24.98	20.55	17.30	20.61	26.66	37.82	55.76
			Charcoal	0.05	0.05	0.04	0.04	0.04	0.03	0.00
		Modern biomass	**Biogas**	0.32	0.29	0.23	0.18	0.12	0.07	0.01
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		**Solar PV**	0.07	0.09	0.13	0.20	0.32	0.53	0.90
			Grid Electricity	2.27	4.19	7.69	12.89	21.48	36.39	63.52
Non-renewable			**Petrol**	1.69	1.65	1.64	1.66	1.70	1.77	1.84
			Diesel	10.47	12.13	14.41	17.58	22.04	28.44	37.68
			Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Furnace Oil	2.28	2.39	2.71	3.08	3.46	3.77	3.73
			ATF**	0.44	0.44	0.44	0.45	0.46	0.46	0.47
			LPG	2.28	2.32	2.37	2.46	2.64	2.97	3.57
			Coal	1.61	1.57	1.51	1.45	1.46	1.06	0.67
Total				**46.46**	**45.68**	**48.48**	**60.59**	**80.40**	**113.31**	**168.13**

In this scenario, the final energy demand would grow at the rate of 4.7% per annum whereas electricity demand grows at an average rate of 13% per annum during 2022-2050. Compared to other energy carriers, electricity demand will be surpassing other energy carriers by 2045. The primary solid biomass (fuelwood, agri -residue and animal dung) demand is expected to grow within the rate of 2% during the same period due to clean energy technology intervention in all major sectors. Policy intervention to reduce petroleum demand mainly in industry and transport significantly shows reduction of its demand in future years. Modern renewables are expected to grow at the rate of 3% per annum during the analysis period. The energy demand trends are highlighted in **Figure 8-14.**

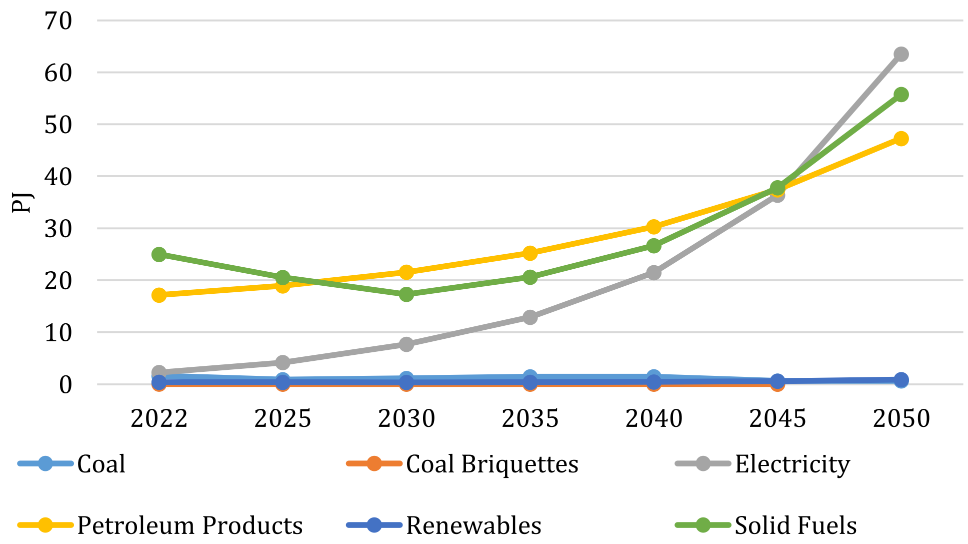
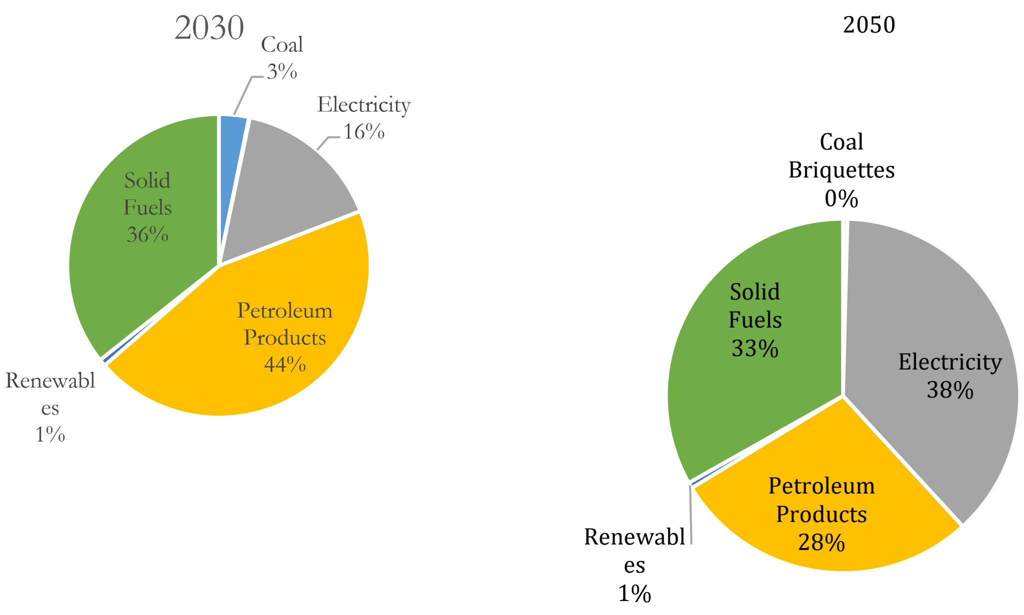


Figure 8-14. Fuel demand trend at Sustainable Energy Development Scenario (SEDS)

The **Figure 8-15**below show the energy mix in the total energy demands for 2030 and 2050 years. The demand of fuelwood is expected to be decreased to 36% in 2030 and 33% in 2050 respectively. The electricity demand would be 16% in 2030 and 38% in 2050 respectively.



(a) Total Final Energy Demand = 48.5PJ (b) Total Final Energy Demand = 168.1 PJ

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

Table**8-11** illustrates the projected energy demand across sectors in this scenario. The residential sector's portion is anticipated to decrease significantly, dropping to 4.6% by 2050 from 42% in 2022. Concurrently, the industrial sector is projected to escalate its share of energy demand to 58% by 2030 and further to 72% by 2050. Meanwhile, the energy demands in the commercial, agriculture, and transport sectors are estimated to stand at 6.5%, 2.7%, and 11.2% respectively by 2050.

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

	2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Agriculture	1.15	1.25	1.53	1.92	2.47	3.29	4.51
Commercial	4.06	3.61	3.36	4.28	5.62	7.69	10.95
Construction and Mining	0.72	0.82	1.09	1.50	2.14	3.18	4.95
Industry	18.04	21.88	28.30	37.98	53.60	79.27	121.25
Residential	19.34	14.84	9.98	9.43	8.86	8.28	7.68
Transport	3.16	3.28	4.21	5.49	7.70	11.61	18.80
Total	**46.46**	**45.67**	**48.48**	**60.59**	**80.40**	**113.31**	**168.13**

Figure 8-16provides a comprehensive view of Province's evolving energy dynamics according to the SED Scenario projected for 2050. The diagram underscores a significant shift away from solid biomass and highlights restrained reliance on imported fossil fuels to fulfill critical energy needs. Notably, within the Gandaki Province, most of the electricity demand is anticipated to be met by clean and renewable sources, signifying a substantial transformation in the energy landscape. This not only enhances regional energy security but also fosters a sustainable approach, aligning with broader environmental goals.

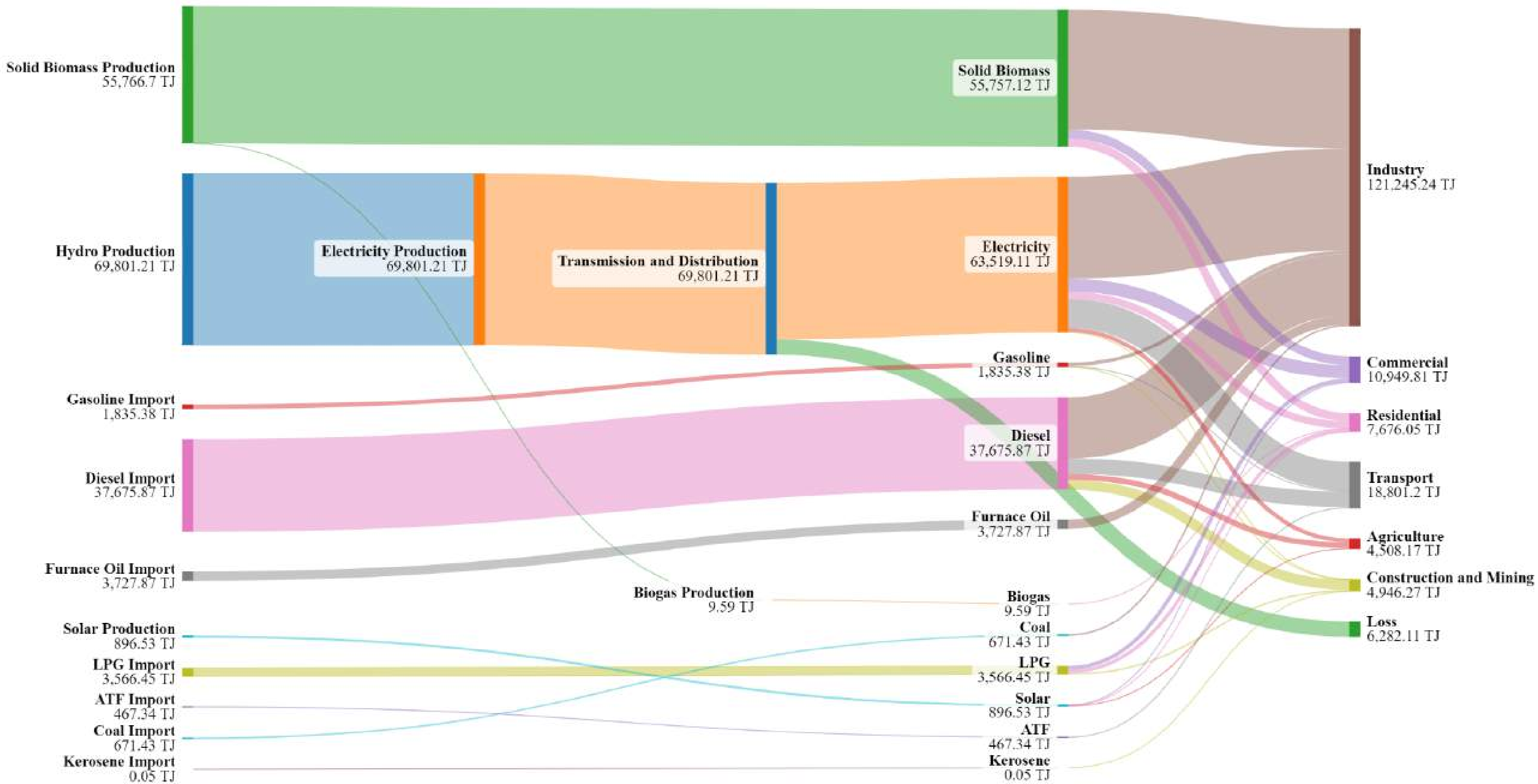


Figure 8-16. Sankey Diagram for Flow of Energy in Gandaki Province for the Sustainable Energy Development Scenario in 2050

The power plant capacity requirement in this scenario, with 30% reserve margin on peak demand, is as shown in **Figure 8-17.** The installed power plant capacity required for Gandaki Province in 2030 will be 972 MW, and it will be about8,000 MW by 2050. This is almost 5 times the requirement in the reference case in 2050. The electricity demand will be 4,300 GWh in 2030 and 35,000 GWh in 2050.

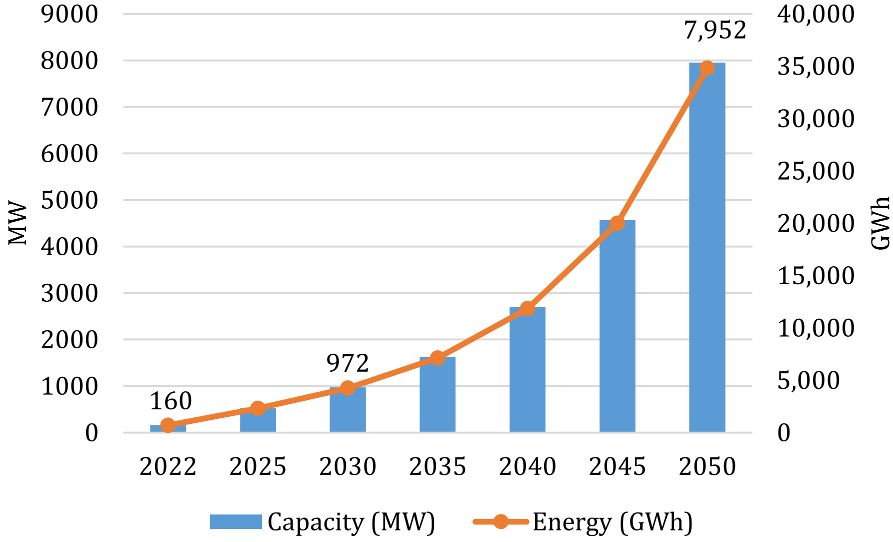


Figure 8-17. Power Plant capacity in Sustainable Energy Development Scenario (SEDS)

GHG emissions trend in Sustainable Energy Development Scenario (SEDS) is shown in **Figure 8-18.** GHG emissions would increase from 1,500 kt in 2022 to 1,800kt in 2030 and to 3,700 kt in 2050. The GHG emissions would grow at the average rate of 3.2% during 2022-2050. Compared to the Reference Economic Growth Scenario, GHG emissions in SEDS would be reduced by 16% in 2030 and by 53% in 2050 respectively. Gandaki Provincewill have the industrial sector as a prominent energy intensive sector. Because of the focus on electrification through renewable energy and energy efficiency in all sectors, economic development has less impact on GHG emissions. This is also in line with the national and international programs in achieving SDGs and mitigation of effects of climate change (Harvey et al., 2018; IEA, 2017; UN, 2015; IEA, 2020; LIFE-AR, 2019; NPC,2016; WB,2020).

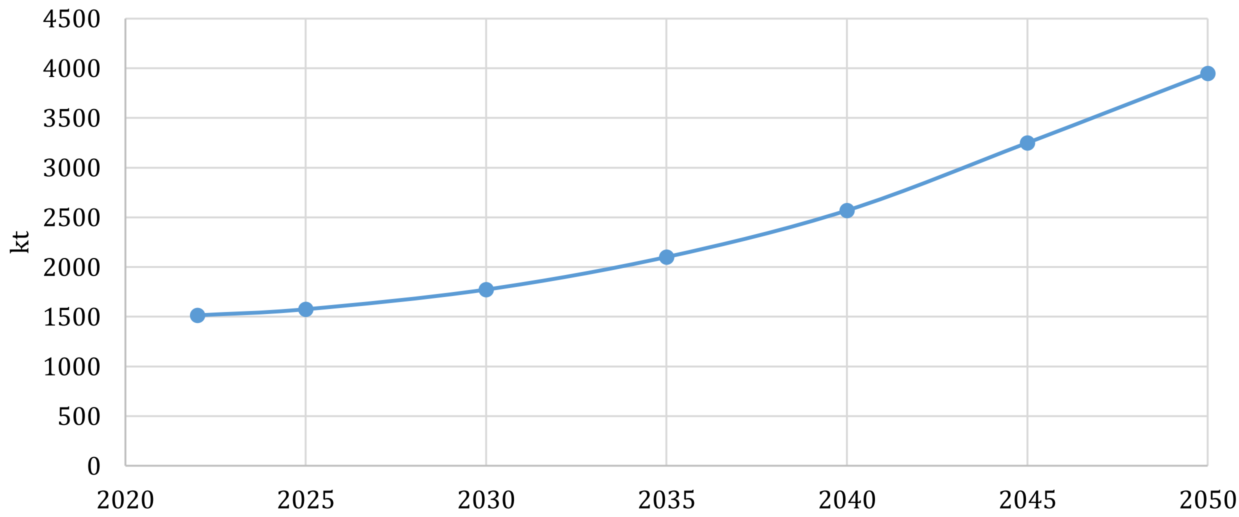


Figure 8-18. GHG emissions at Sustainable Energy Development Scenario (SEDS)

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

Table 8-12 shows the energy indicator for policy scenario i.e. SEDS which clearly presents the impacts of strategic interventions in energy sector. Per capita final energy demand is 95% of that in Reference Economic Growth Scenario in 2050, while the electricity – which comes from clean renewable resources – increases to over 6,729 kWh per capita. The impact of energy efficiency is visible in energy demand per capita as well as energy required per millions of GDP as well. In addition to this, the share of fuel imports decreases to 29% of total energy from 57% in reference scenario in 2050. On other hand, use of national resources increases with increase in use of renewables to 38% in 2050 as compared to only 9% in the Reference Economic Growth 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	18.74	18.28	19.17	23.65	31.00	43.14	63.22
Final electricity demand	kWh/capita	262	476	859	1,420	2,336	3,905	6,729
Final energy demand	GJ/million NRS	124	108	87	80	78	78	81
Final Electricity Demand	kWh/million NRS	1,739	2,789	3,834	4,666	5,447	6,204	6,962
Total Electricity Used/household	kWh/HH	410	485	611	738	864	990	1,116
Share of renewable energy in final total energy demand	per cent	5.73%	10.00%	16.62%	21.91%	27.28%	32.64%	38.32%
The ratio of net import to total primary energy supply	per cent	40.38%	44.90%	47.60%	44.02%	39.50%	33.96%	28.52%
GHG emissions	GHG in Kg/capita	610	631	696	807	945	1,110	1,381

From the above table of energy indicators, it is obvious that Energy Intensity of output (GDP) of Gandaki Province in 2022 is 0.39t/US$1,000. It is the highest compared to thevalues in other South Asian Countries. The Global Energy Intensity of output is around 0.16 t/US$1,000 (WB, 2023). BY 2050, Gandaki Province will be able to achieve the current global level of energy intensity in the SED Scenario.

8.2 Comparative Analysis

Figure 8-19shows the final energy demand for the reference (REF) and policy (SEDS) scenarios which clearly shows the impact of fuel switching and energy efficiency. With lower growth rate of 4.7% instead of 4.9% in REF scenario, the total final energy demand could be reduced by nearly 14% in 2030 and about5% energy savings in in 2050. Although the energy saving does not look as significant, it is to be noted that the energy mix changes significantly – from imported petroleum fuels to indigenous renewable and clean energy.

The difference in energy demand projectionof both the REF and SED scenarios seems not significant. It is because of the focus on usage of primary solid biomass in the food and beverage industries for thermal energy production in boilers and furnaces as solid biomass is carbon-neutral and indigenously available. In the workshops, there were suggestions from the participants for the use of solid biomass in the energy sector as in some parts of the country, solid biomass remains unused and wasted.

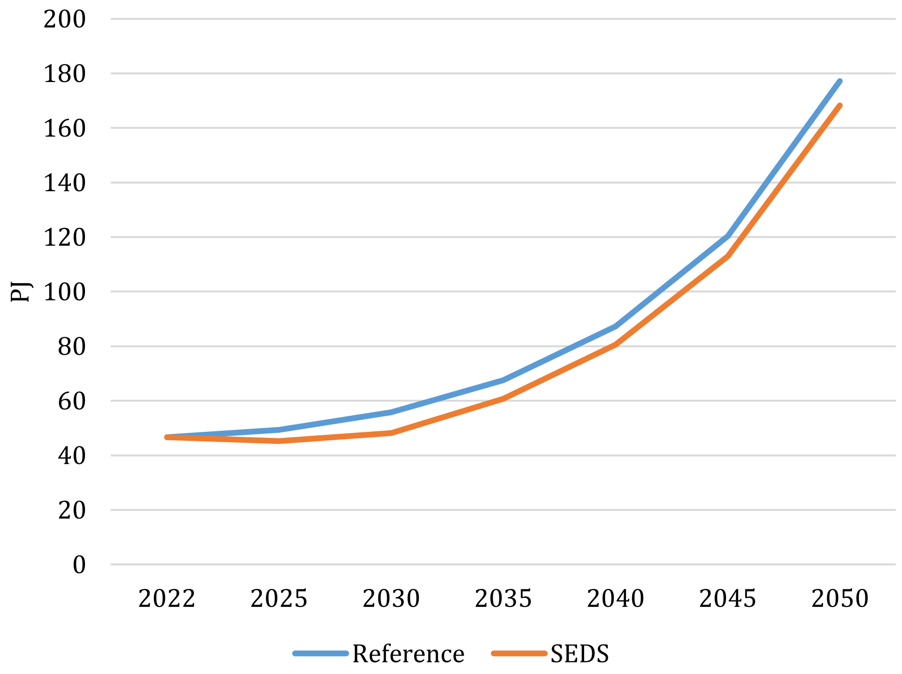


Figure 8-19. Total Final Energy Demand in Gandaki Province

A similar trend is seen in per capita energy consumption (**Figure 8-20),** with seemingly similar reduction in energy intensity. Since the energy intensity in industrial sector increases more than population, the gap of energy intensity improvement is not seen overall.

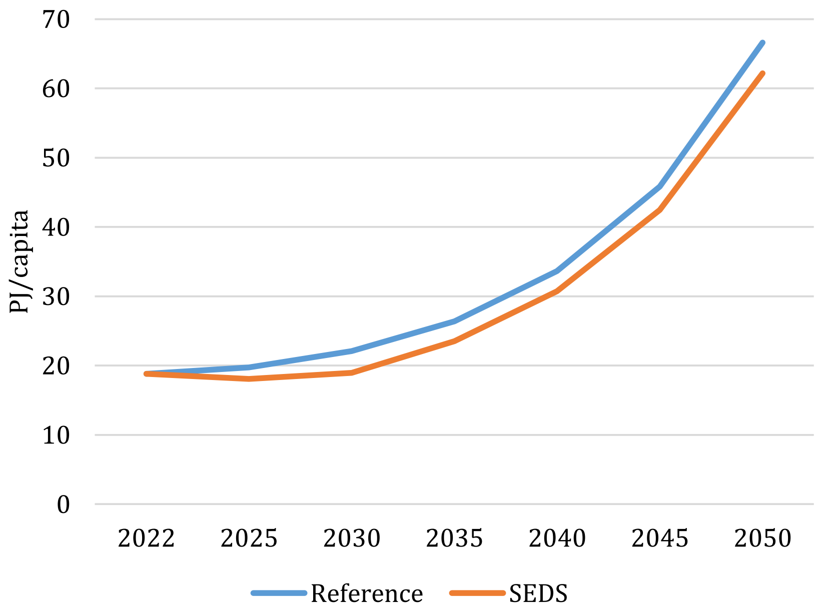


Figure 8-20. Final Energy Demand per capita in Gandaki Province

Figure 8-21depicts the electricity demand in compared scenarios which shows that in the SEDS, the electricityThe total electricity consumption will grow at very high rate reaching over6,729 kwh per capita in overall due to electrification in possible areas. Meanwhile, the household electricity demand reaches 1,116 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 meansan increase in demand for nationally available hydroelectricity production.

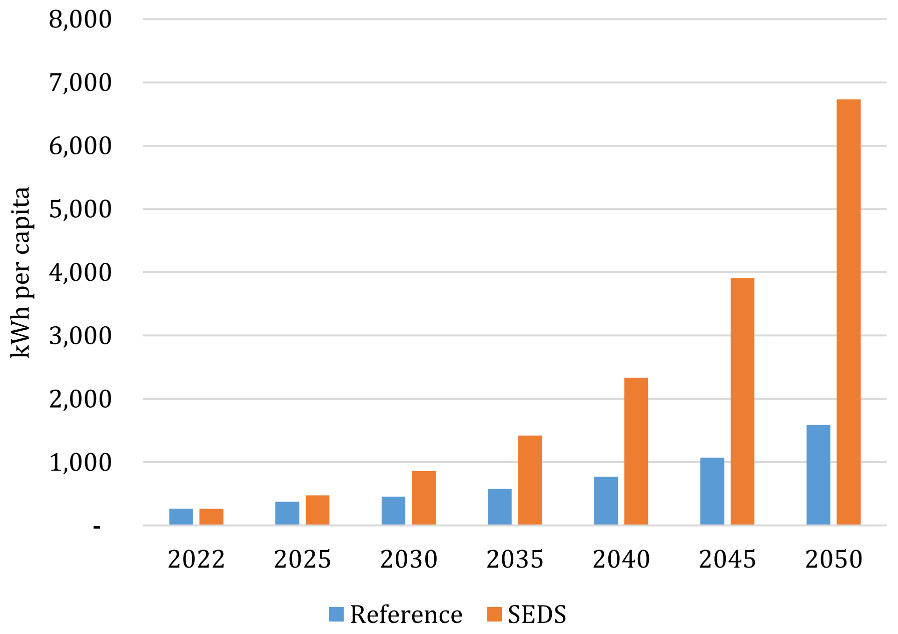


Figure 8-21. Electricity Demand per capita in Gandaki Province

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 6% in 2022 to 38% in 2050, provided that enough hydropower and power from solar PV are developed provincially and nationally.

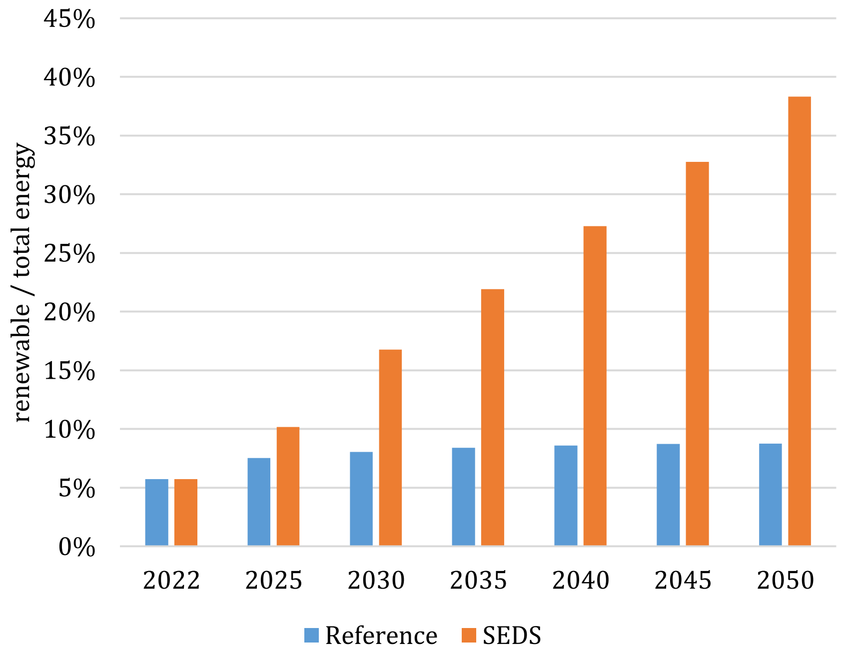


Figure 8-22. Renewable Energy to Total Energy Demand Ratio in Gandaki Province

The effect of energy development and production from indigenous resources reduces the pressure on fuel dependency which is depicted in **Figure 8-23.** There seems to be no improvement in the net import to total final energy ratio till 2030 because of rapid intervention of ICS. Meanwhile, ratio of 57% in the Reference scenario would come down to 29% in the SEDS in 2050 with the enforcement of policy actions and thus, strengthening the energy security of the country and reducing outflow of foreign currency. Consequently, it can enhance the balance of the payment of the Gandaki Province and the country.

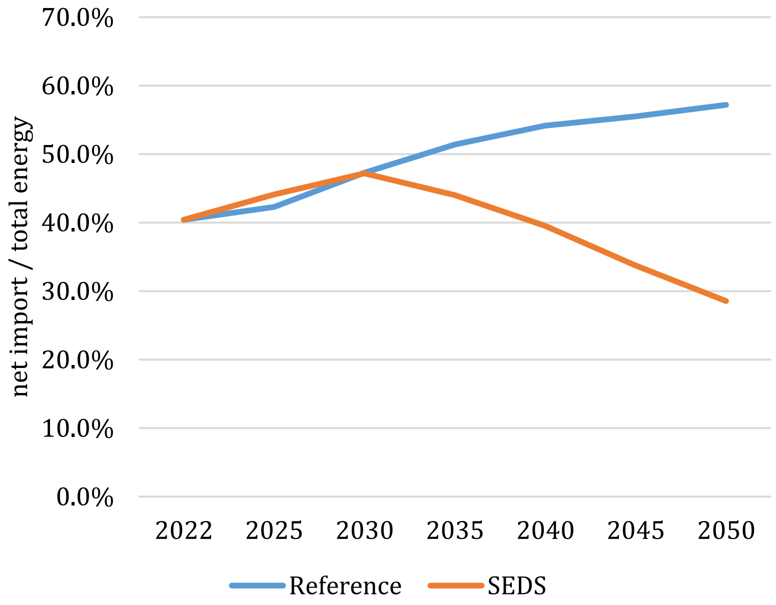


Figure 8-23. Petroleum Import to Total Energy Ratio in Gandaki Province

Figure 8-24shows the impact in GHG emissions due to policy interventions of clean energy. Emissions which were growing at the rate of 6% in the Reference Economic Growth Scenario would increase at the rate of only 3.2% resulting in the GHG emissions reduction of 16% 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) positive economic perspective -by monetizing the emission reduction by carbon trading.

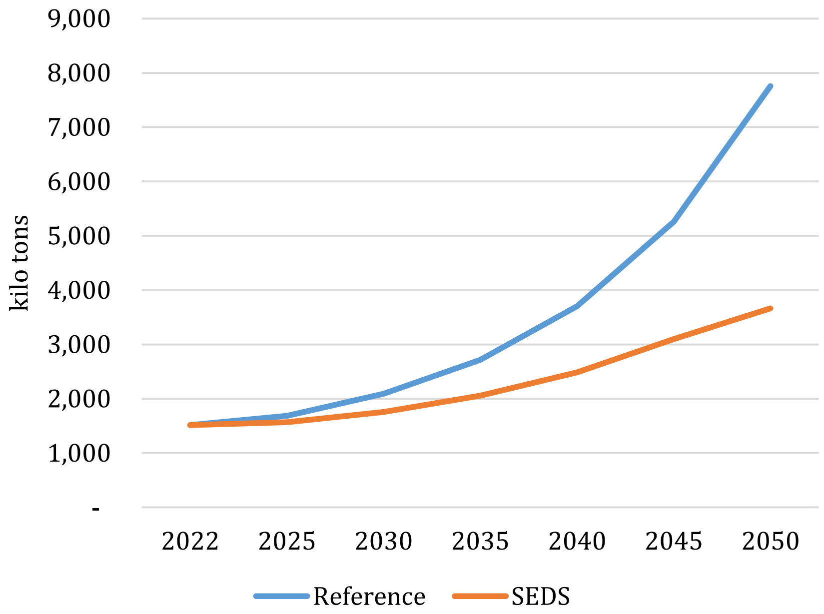


Figure 8-24. GHG Emissions in Gandaki Province

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 REF scenario, the hydro power plant capacity requirement in the SEDS would be about 980 MW i.e., 86% more in 2030 and up to triple additional power plant capacity of 8,000 MW is required in 2050 as shown in **Figure 8-25.**

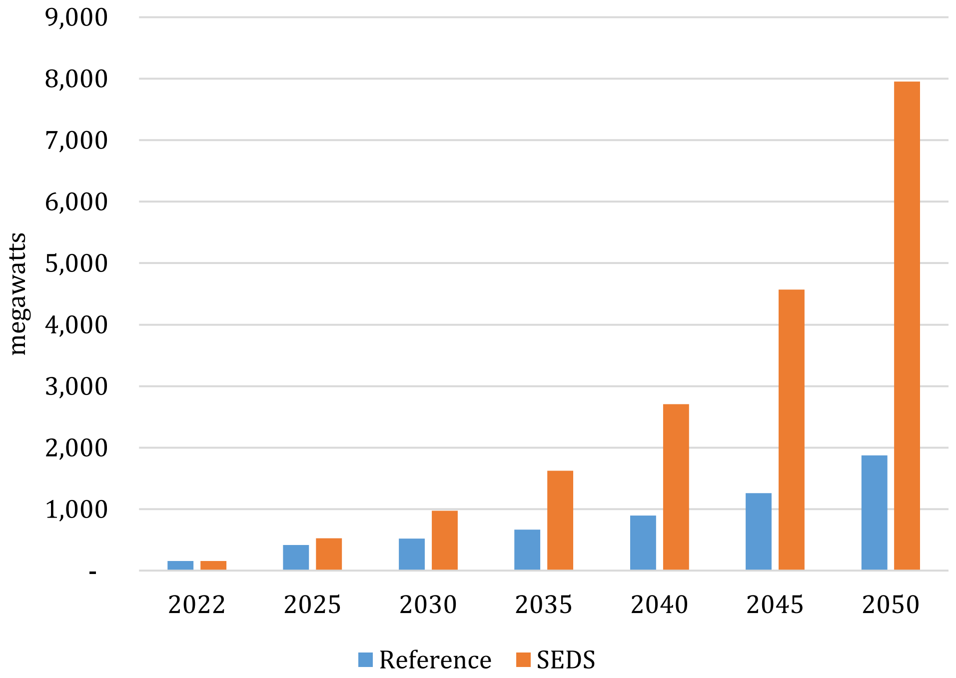


Figure 8-25. Hydropower Plant Capacity Requirement in Gandaki Province

8.3 Provincial comparison

Comparing the energy consumption of Gandaki Province with the rest of the province, the total consumption of the province is 5th highest among the seven provinces. One of the major reasons for such lower consumption in Gandaki Province is the lower number of industries here than in the former four provinces that have higher energy consumption. Secondly, the overall population of the province is also lower, causing a lesser demand for energy (**Figure 8-26**).

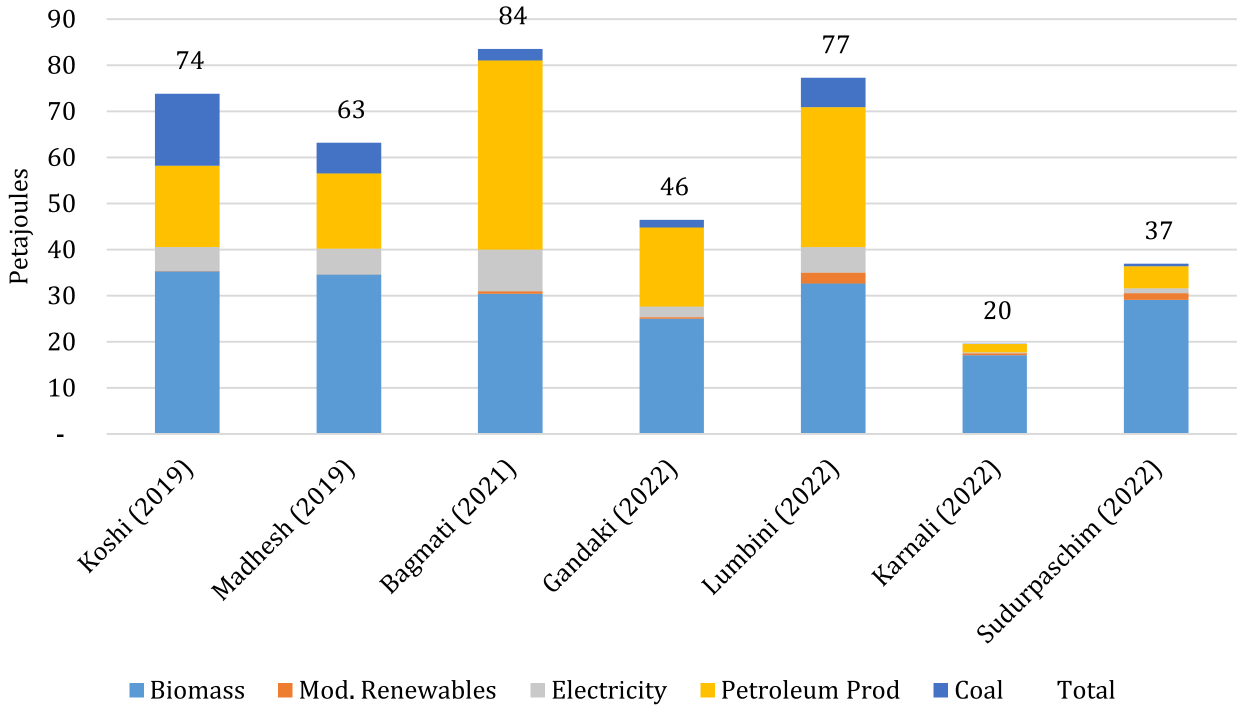


Figure 8-26. Provincial Comparison of Energy by Fuel Types

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

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

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

9. Economic Analysis

There are strong interactive linkages among energy, economics, and the environment. A comparative analysis has been conducted between these segments in the Reference scenario and the SEDS. This kind of analysis is essential for the policymakers to take necessary implementation actions in the energy sector of Gandaki 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 the REF scenario, the gross investment share in supply technologies is around 3 % of GDP on average. In SED scenario, new and efficient technology interventions are done. To achieve the sustainable developments goals, capital investment should increase to 18% of the provincial GDPin 2030 and to20% in 2050 respectively. The high investment in SED scenario is mainly due to the investments required in hydropower plants to meet the growing electricity demand because of electrification in all major end uses. These figures can be accounted for the large-scale investment required in the hydropower development and industrial capital costs (**Table 9-1)**

In the case of Gandaki Province, which has huge resources and feasibility for development of hydropower plants, the province needs to invest on hydropower development. Thus, the capital investment as given in **Table 9-1,** would be required to develop the power plants in the province. In addition to this, the province can build up solar power plants (off grid and utility) within the region for daytime supply at peak solar insolation hours of the day.

Table 9-1. Total Technology Cost for different scenarios

	2025	2030	2035	2040	2045	2050
Investment in the REF scenario in NR billion	10.73	16.79	24.45	34.96	50.01	74.05
Capital Investment as % of GDP	2.52%	2.96%	3.14%	3.14%	3.03%	2.88%
Investment in the SEDS scenario in NR billion	40.29	103.54	174.09	258.67	359.00	505.57
Capital Investment as % of GDP	9.45%	18.26%	22.33%	23.26%	21.72%	19.67%

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 researchworking paper of the World Bank for infrastructure development in emerging markets and developing countries, investment costs come around 6% of the GDP in the energy sector in the South Asia region (Ruiz-Nunez, F. and Wei, Z., 2015). As GHG emissions will be decreased by almost 50% in 2050 in the SED scenario, the Government of Nepal must seek international climate grants and finance funds, international financial institutions, and domestic private finances for the development of power plants required in the country.

9.2 The Marginal Abatement Cost

GHG emissions for reference scenario and SEDS scenario is shown in **Figure 9-1.** It shows that there is quite a reduction of GHG emissions in SEDS scenario. In 2030, the reduction of emission compared to that of base case scenario is16%, and 53% in 2050. This considerable reduction of GHG emission accounts for efficient and modern technology.

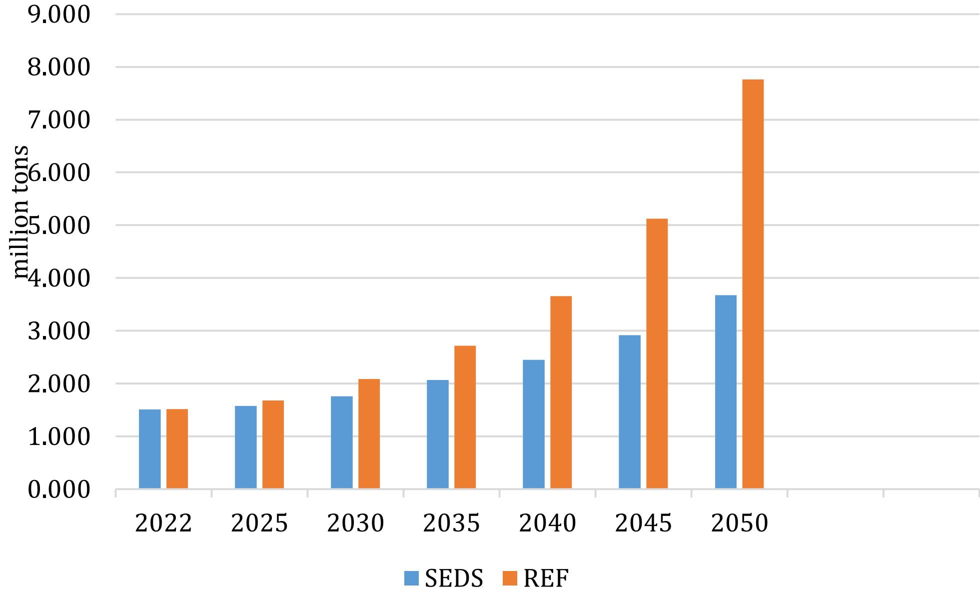


Figure 9-1. GHG Emission for Different Scenarios

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

Table 9-2. Marginal Abatement Cost

	2025	2030	2035	2040	2045	2050
Incremental Investments (Billion Rs.)	29.56	86.75	149.65	223.71	308.99	431.52
GHG abated (kt)	100.94	325.78	648.60	1207.67	2212.15	4087.41
MAC ('000 NPR/ton of CO_2e)	292.83	266.30	230.72	185.24	139.68	105.57

9.3 Net Fuel Import Cost

Figure 9-2 shows the implication of the SEDS scenario in terms of saving in net import of petroleum fuels. It is seen that the saving is substantial under the SEDS scenario counting over 14 billion NRs in 2030 and 429 billion NRs in 2050 compared to the 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 16% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute nearly 99% of the investment required. This indicates a significant reduction in dependency on imported fuel. Policy intervention to promote modern and efficient indigenous energy sources will hence improve energy security of the nation. These savings 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.

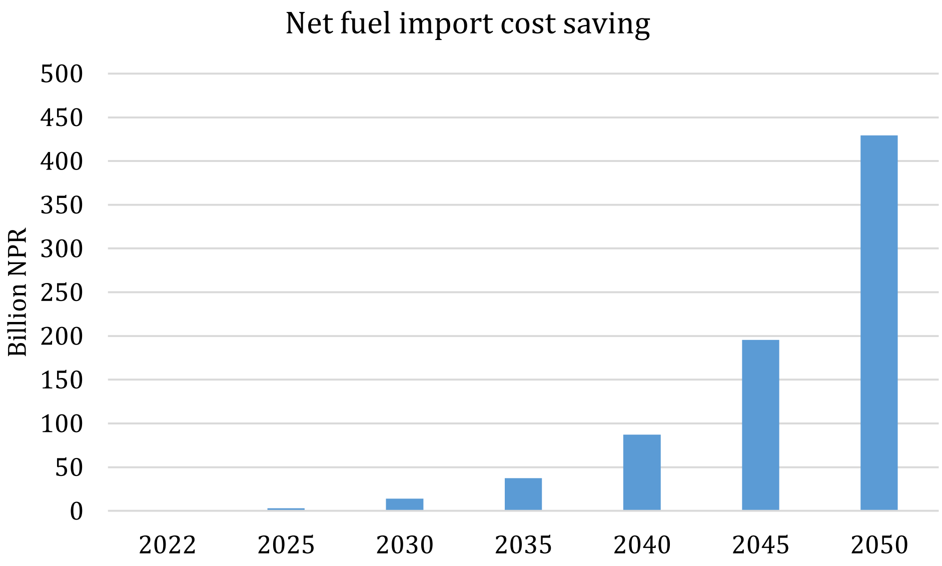


Figure 9-2. Net Fuel Import Cost Savings

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)	1.04	2.49	5.90	14.06	9.82	23.43

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

10. Limitations and Constraints of the Survey

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

- The primary and secondary data on the current situation of the province were not available at the most, which is needed during the pre-planning phase of the study and also required for the post-analysis of the energy consumption – such as the population of the sector; the gross value added of each type of economic sector and subsector; the number of vehicles by type and registration; the types of 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.
- 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 such as power rating, capacity etc.
- 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 hunch or based on their memory and in many cases such as residential, agricultural, and small commercial entities do not keep a record of their energy uses.
- The newly added construction and mining sector also had major difficulties in the collection of data. This sectorial entity is not locally based and/or brings heavy equipment (such as land movers, road rollers, excavators etc) from other regions when necessary for the limited time as per requirements. Thus, their energy consumption had to be based more on overall yearly energy consumption than on each end-use activity.

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

11. Conclusion and Policy Recommendations

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

The study is related to energy consumption determined through primary sample surveys and the energy supply situation is based on secondary resources in the Gandaki Province. It has focused primarily in six economic sectors of Nepal viz. – agricultural, commercial, construction and mining, industrial, residential, and transport. The main demand driver of economically active sectors - except residential, is gross value added while that of residential sector is taken as population. In addition to that, a situational analysis of macroeconomic indicators of Gandaki Province and socio-economic analysis in the residential sector based on the survey have been carried out.

In the year 2021/2022, the primary sample survey shows that the total final energy consumption of the Gandaki Province was 46,462 TJ which accounts for 18.74 GJ per capita. This energy consumption per capita seems to be lower than the national average (WECS,2023). The shares of energy consumption in economic sectors of the Gandaki Province indicate some differences from the national level energy consumption pattern. Residential and Industrial sectors consume 42% and 39% of total energy consumption respectively. However, the share of energy consumption in the industrial sector, compared to national level, is quite high due to industry bases in the province. Transport sector consumption is 7% and commercial 9% respectively. One prominent feature is the final energy consumption in the agriculture sector, and it stands at 2% which is almost like the figure for the national level. As for energy consumption by fuel types, the use of biomass is still prevalent at around 54%. Petroleum products are 37% of the total energy consumed in the province, coal is 4% and electricity is5%. Modern renewables account for 0.8% of the total energy and they are mostly from biogas plants.

As per ecological regions, Gandaki Province has three regions – Terai, Hills, and Mountain regions. Hilly region has the highest consumption with 72% of the total consumption in the province, which is followed by terai region at 19%, and the least in the mountain region at 1.2%, and the remaining is consumed in the transport and construction and mining sectors, which is at 7% and 2% of the total consumption respectively. Terai, Hilly,and Mountain regions consume fuelwood at 6%, 92%, and 2% respectively of the total energy consumed in the province, while fossil fuels and electricity consumptions in the Hilly region are high with 54% and 73% respectively of the total which is understandable with the concentration of industries in the region. Fossil fuel consumption in the Terai region is 25% of the total provincial consumption. LPG consumption in hilly region is around 83% of the total, followed by 13% in the hilly region, and the remaining 1% in mountain region respectively (4% in being consumed in construction and mining sector at different regions).

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 Reference Economic Growth (REF) scenario, primary solid biomass occupies 54% in 2022, 45% in 2030 and 34% of the total final energy demand in 2050 respectively, whereas petroleum products reach from 37% in 2022 to 56% in 2050. Electricity demand will be 7% in 2030 and 8% in 2050.Butper capita electricity in the REF scenario attains 457 kWh/capita in 2030 and 1,586 kWh/capita in 2050 respectively. The current pace of electricity consumption may not be able to achieve the SDGs as per the roadmap of National Planning Commission (NPC) in 2030.The installed capacity of the power plant will be 520 MW in 2030 and 1,900 MW in 2050 respectively. GHG emissions/per capita 825 kg/capita in 2030 and 2,918 kg/capita in 2050 respectively. Due to poor economic development status and industrialization, GHG emissions in the Gandaki Provinceare still low compared to other developing countries.

In the Sustainable Energy Development (SED) scenario, all combined policy measureswith technology and interventions are considered to be implemented in time.In this scenario, the final energy demand would grow at the rate of 4.7% per annum whereas electricity demand grows at an average rate of 13% per annum during 2022-2050. Solid biomass fuels in the total final energy will decline from 53% in 2022 to 33% in 2050. Petroleum products will occupy from 37% in 2022 to 28% in 2050 respectively. Electricity demand will reach 38% in 2050 from5% in 2022. The major thrust is the electrification in most of the economic sectors. In this SED scenario, the installed capacity of power plants will reach972 MW in 2030 and 8,000 MW in 2050 respectively. Per capita electricity consumption will attain 859kWh/capita in 2030 and 6,729 kWh/capita in 2050 respectively. Though this indicator is slightly lower than the target set in the NPS's roadmap in 2030, but it reaches consumption in the middle-income countries in 2050. GHG emissions/capita will be 696 kg/capita in 2030 and will reach 1,381 kg/capita in 2050. This is of course lower than in the REF scenario.

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Gandaki Province indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and the sustainable energy development in the national context.the total consumption of the province is 5th highest among the seven provinces due to the lower number of industries and lower overall population of the province causing a lesser demand for energy. This study also indicates that with the core focus on energy security, reliability, and sustainability, Gandaki 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.

Policy Recommendations

- **Energy Generation Capacity Development**

  The analysis shows that the demand for energy, especially for electricity, is going to increase at a higher rate if sustainable energy development goals are to be achieved. The under construction and planned plant capacities are supportive, but in the long run, they might not be enough to cater for the burgeoning electricity demand to meet the national commitments and international pledges. Thus, the province should focus on more power plant capacity development, including the integration of utility scale variable renewable energy generation plants like Solar, MHPs etc.

  Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center; Nepal Electricity Authority; Gandaki Province Training Academy

- **Energy Infrastructure Development**

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

  Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Ministry of Physical Infrastructure Development and Transport Management- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Nepal Electricity Authority

- **e-Cooking Promotion**

  Given that the province has very low penetration of electric cooking technology users, the province should promote the use of e-cooking wherever possible. The province, having a good commercial activity especially in tourism sector, can motivate the commercial sectors to adopt eCooking. With expanded reach and capacity development for technology, electricity and awareness, full-fledged electrification in cooking end-use can be promoted for all residential and commercial sectors. E-cooking can have multitude of impactful benefits – it is a clean cooking solution with no indoor air pollution, it creates internal demand for electricity, it reduces LPG imports, it is the most efficient of all cooking technologies and it is economically cheaper.

  Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Ministry of Industry, Tourism, Forest, and Environment- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Alternative Energy Promotion Center; Nepal Electricity Authority

- **Energy Demand Creation**

  In the province, energy consumption is lower compared to more economically developed regions, presenting an opportunity for demand creation, particularly for electricity. Currently, there is excess electricity production in the nation in wet seasons, risking wastage if demand is not stimulated. By fostering demand, especially in industries and commercial sectors, the province can boost economic output and enhance its overall status. Increasing energy demand aligns with broader development goals, ultimately contributing to the prosperity and advancement of the province.

  Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Ministry of Agriculture and Land Management- Gandaki Province; Ministry of Physical Infrastructure Development and Transport Management- Gandaki Province; Ministry of Industry, Tourism, Forest, and Environment- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center; Nepal Electricity Authority

- **Energy Efficiency Regulations**

  In the 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, Gandaki Province can optimize its energy use, spur economic development, and contribute to a greener future.

  Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Ministry of Industry, Tourism, Forest, and Environment- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center

- **Clean Energy Regulations**

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

  Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Ministry of Agriculture and Land Management- Gandaki Province; Ministry of Physical

Infrastructure Development and Transport Management- Gandaki Province; Ministry of Industry, Tourism, Forest, and Environment- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center

- **Renewable Energy Commercialization**

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

Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Ministry of Industry, Tourism, Forest, and Environment- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center

- **Database Management**

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

Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center

- **Awareness Creation and Capacity Building**

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

- *Actors: Ministry of Energy, Water Resources and Drinking Water- Gandaki Province; Provincial Policy and Planning Commission- Gandaki Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center; Gandaki Province Training Academy*

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Gandaki Province indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and the sustainable energy development in the national context. the total consumption of the province is 5^{th} highest among the seven provinces due to the lower number of industries and lower overall population of the province causing a lesser demand for energy. This study also indicates that with the core focus on energy security, reliability, and sustainability, Gandaki Province/Nepal’s energy development should be geared towards 5 energy transition aspects – (a) Sustainable Energy Development Policy, (b) Hydropower/renewable Energy Development, (c) Infrastructure Development, (d) Creation of Domestic Power Demand and Exploration of Power Markets in the South Asia, and (e) Reduction in Demands for Fossil Fuels.

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