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Water and Energy Commission Secretariat
Singha Durbar, Kathmandu
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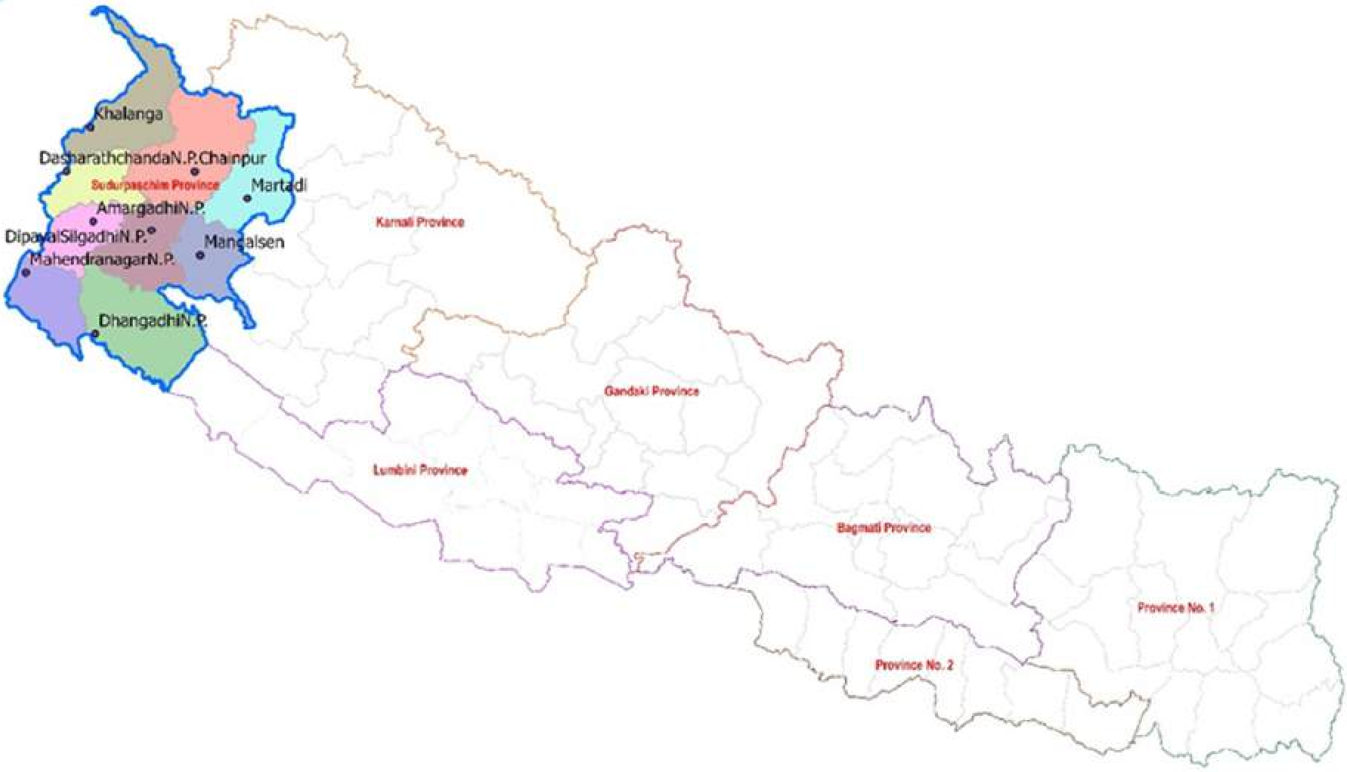
Final Report

(Sudurpashchim 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_2 emissions is emitted from the energy sector. The adverse impacts of climate change have become severe leading to a strong global commitment to curtail GHG emissions to limit temperature rises to 1.5 ^{0}C by the end of twenty first century. Hence, most countries are on the pathway to transition their energy systems to cleaner energy developed from renewable sources.

The world saw a global pandemic at the end of 2019 causing global energy consumption to decline tremendously. However, in the wake after the COVID - 19 pandemic, energy production from renewables are strongly moving forward. Renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records. World Energy Outlook 2023 (IEA, 2023) indicates that fossil fuel prices have declined from their 2022 peaks, but markets are tense and volatile due to continued disputes in Ukraine and escalation of new war in the Middle East. The global average surface temperature is already around 1.2^{0}C above pre-industrial levels causing wild forest fires, floods, rise in sea levels, heat waves, and glacial flash floods across the globe. The energy sector accounts for the primary reason of the polluted air that more than 90% of the global population are forced to breathe, which causes more than 6 million premature deaths in the world. Against these climate - related catastrophic events and anthropogenic causes, the growing emergence of clean energy economy, bolstered by solar and electric vehicles, provides a strong hope for the way forward.

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

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

Objective and Scope of Study

Objectives

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

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

Scope of the Study

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

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

- Total and Specific energy consumption of all districts of each Province in all economic sectors by each fuel type, end uses, and energy technologies/devices used were provided.
- Energy supply and demand of each Province at different physiographic regions and with different growth scenarios in all economic sectors were determined.
- The potential of all type of energy resources of each Province was determined based on the available secondary data/information.
- The study was carried out for all districts of each Province including three physiographic regions (Hill, Mountain and Terai) for the sample survey.
- Major statistical information of the energy consumption in each Economic Sector at district and provincial level was assessed during the survey. Especially the average energy consumption, standard deviation/variation, coefficient of variation, standard error of the mean 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 sector was collected from the latest reports of concerned authorities.
- A detailed survey questionnaire for each economic sector was prepared separately by the consultant and sample survey was carried out only after the questionnaire has been approved by the WECS. The questionnaire would also address the peak and the off-peak time of energy consumption.
- Before conducting the Energy Consumption, Supply and Demand survey, training program for the enumerators, field supervisors and WECS staffs was organized.
- A letter certifying the work carried out from the concerned surveyed commercial, industrial, agricultural and construction and mining company/institution/firm etc. was submitted to the WECS along with the survey report based on the supply of these letters from the concerned organizations. The official authenticated letter included the name and contact number of the concerned person of the concerned institution and was submitted to WECS after completion of the field work in Field/Interim report.

Sudurpashchim Province

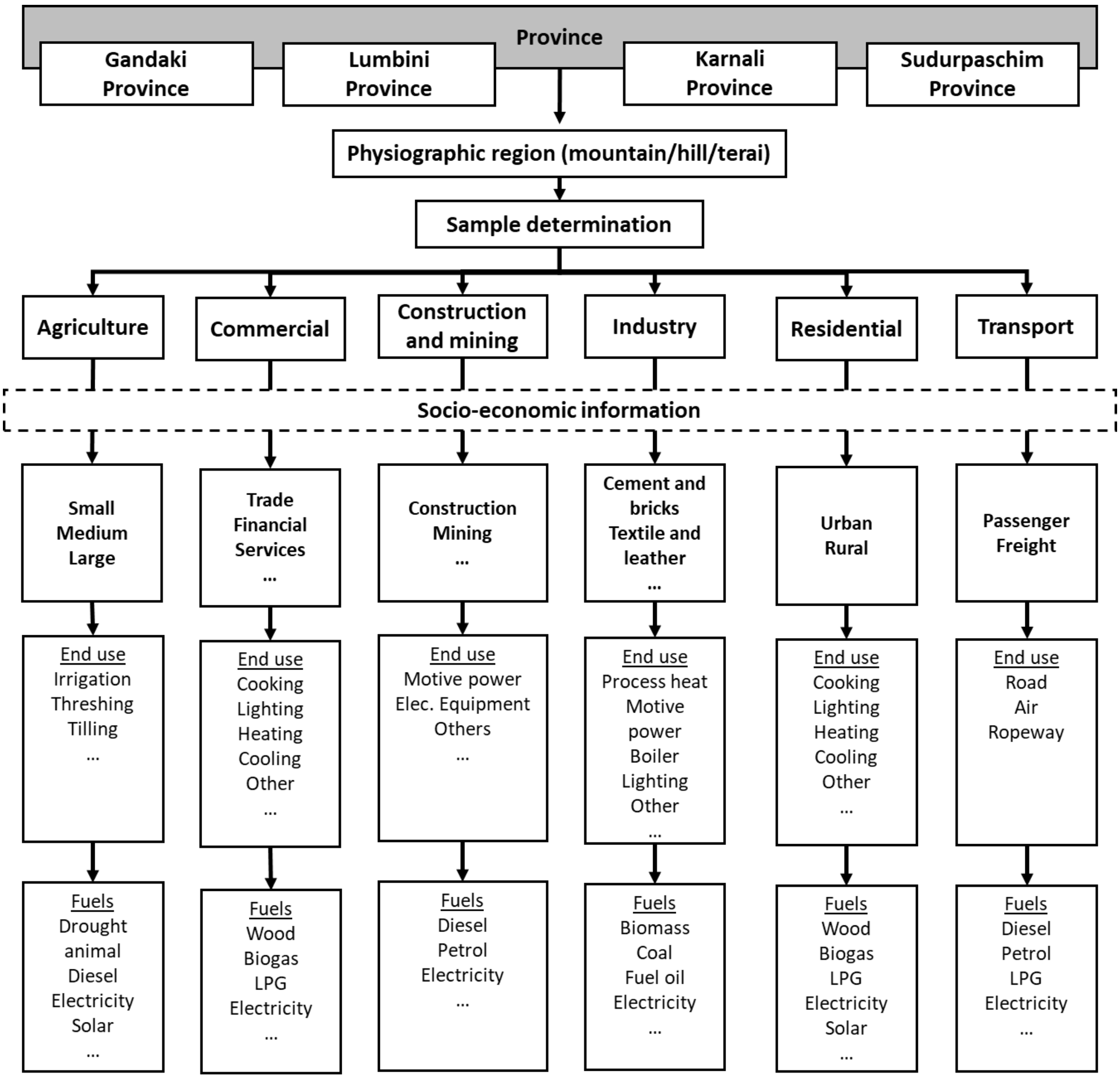
Sudurpashchim Province covers a geographical area of 19,515.52 km^{2}which is 13.22% of the country's total area. Godawari has been declared the capital of the province which will be replacing Dhangadhi as the provisional administrative headquarter of the province. The three major and populous cities in the province are Dhangadhi, Bhimdutta (Mahendranagar) and Tikapur, which are also major trade and commercial centers in the province. Sudurpashchim Province borders the Tibetan Autonomous Region of China to the north, Karnali Province and Lumbini Province to the east, and India's Uttaranchal state to the west and Uttar Province to the south.

The past normal pace of economic growth in the country as well as in all provinces was disturbed and badly affected by the pandemic of Covid-19 in FY 2019/20. The GDP growth rates of all provinces except Karnali and Sudurpashchim Provinces were negative. The share in GDP of Sudurpashchim Province was 6.9% of Nepal in FY 2020/21, which has marginally decreased from 7.0% in the last FY 2019/20. The composition of provincial GDP of Sudurpashchim in 2020/21 shows that service sector contributed the largest share to its provincial GDP at 52%. Agriculture and industry sectors covered 34% and 15% respectively.

Methodology for Study

The methodological approach was conducted systematically identifying the steps in collection, analysis, and synthesis of information from different sources. The basic disaggregation for the sample survey is bottom up for every sector for energy as well as socio- economic information. The categorization followed a framework like given in Box 1 for Sudurpashchim 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 Sudurpashchim Province.

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

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

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

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

The energy system analysis was done from the bottom-up approach, i.e., all possible energy activities was considered at the end-use level for each sector. The base year was taken as 2022 for energy consumption analysis. From here, energy scenarios have been developed until 2050, and short term, medium term, and long-term targets have been devised. The initial data collected from the survey 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 was 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 Sudurpashchim Province

Solid Biomass Energy

Sudurpashchim Province of Nepal is blessed by nature with lush forests in terai, dun valleys like Jogbudha, mid hills, and high hills. As compared to other provinces of Nepal, this province has more forest area per person. In addition, there is good sunlight, enough water in the watersheds of Karnali and Mahakali rivers, and abundant alluvial soils. Although deforested to some level, there is still good forest cover throughout the province. But urbanization and agriculture have encroached on good forest land which is prominent especially in Kailali and Kanchanpur districts. Similarly, human pressure for fuelwood in the past has led to overcutting of trees. Despite this, Sudurpashchim Province still has good potential for forest management and production with its rich soil and history of community forestry. These forests have very high energy potential for the locals who are poor and depend on them as a cheap source of bio energy. Thus, annual fuelwood from the whole Sudurpashchim Province is 2,762,278 m^3 (This is a harvestable quantity). By weight, the annual fuelwood potential is 2 million tons. Animal dung potential in the province comes to around 6.5 million tons. Agriculture residue has a potential of 30 PJ.

Petroleum Products

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

Table 1. Petroleum Sales in 2077-78 in Sudurpashchim Province

Districts	MS	HSD	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Accham	612	3,495	-	-	-
Baitadi	-	2,762	-	-	-
Dadeldhura	685	3,819	-	-	-
Darchula	150	2,100	-	-	-
Doti	528	3,466	-	-	-
Kailali	15,846	55,786	679	1,656	13,198
Kanchanpur	8,280	23,752	24	-	-
Total	**26,101**	**95,180**	**703**	**1,656**	**13,198**

(NOC, 2022)

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

Electricity Supply

AS per NEA 2080 distribution report, 82% of households have access to electricity in Sudurpashchim Province. Sudurpashchim Province has a potential of 7,722 MW, which comes to be 11% of the total national hydropower potential (WECS, 2019). NEA has developed hydropower plants and has projects under proposed plan totaling 240 MW in the Sudurpashchim Province and the IPPs have existing 145MW and planned and under construction in the range of 445 MW hydropower plants (DoED 2023). Electricity sales in the province in 2022 was 286.25 GWh. Distribution loss in the province is 11%. It has the second lowest sales, except Karnali Province, among all 7 provinces in Nepal (NEA,2022).

Modern Renewables

There are 6.30 MW of micro and mini hydroelectric power plant installed in the Sudurpashchim Province. There are 140,000 SHS systems and 908 kW of institutional solar PV systems in the province. There are 51,000 domestic biogas plants installed. 87,000 mud ICS and 4,600 metallic ICS have been installed in the province (AEPC, 2022).

Energy Consumption in 2022

The total final energy consumption (FEC) in Sudurpashchim Province was found to be 36,919 TJ. Among the six sectors, the residential sector is the highest energy-consuming sector followed by industries. The highest share of energy consumed is still the biomass used particularly in the residential sector for cooking. In this province, 70% of households still use biomass cooking stoves, 17% of households use LPG and just 0.3% of households' cook on electricity.

Figure 1 and Figure 2 show the energy consumption as per fuel mix and consumption in different economic sectors. In Sudurpashchim Province, the use of fuelwood is still the major resource among biomass used mainly for cooking and water heating purposes in the residential sector (**Figure 1**). The use of agricultural residue is seen to be significant in the industrial sector for thermal purposes. The use of biogas has reduced considerably although it is increasing in number, as the actual use is very little. This can be mainly attributed to the growing consumption of LPG, decreasing livestock farming, people's reluctance to operate residential biogas plants, and due to lower production in colder regions.

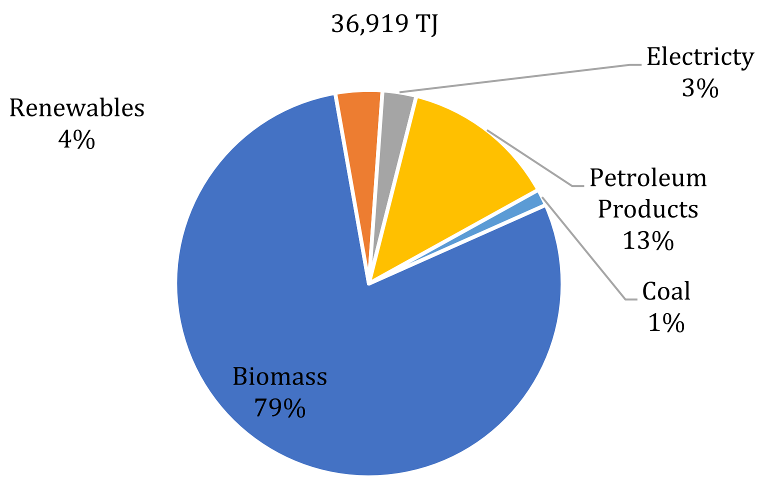


Figure 1. Energy Consumption Share in Sudurpashchim Province by Energy Types

Figure 2 also indicates the change in the consumption pattern in different economic sectors. With the residential being the highest energy-consuming sector at 73% of the total energy consumption, the use of biomass is prevalent in the energy mix. The industrial sector is second at 16% followed by the commercial and transport sector at 3% each. Since there are limited economic development activities, most of the energy is consumed in non-productive activities.

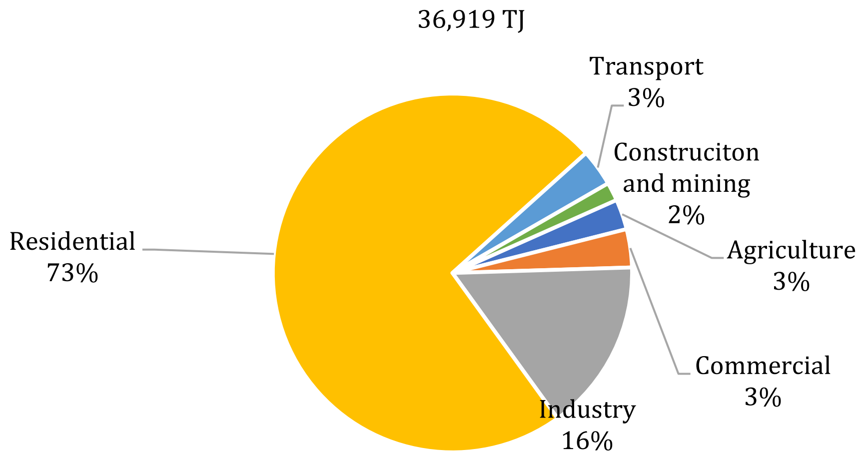


Figure 2. Energy Consumption by Sectors in Sudurpashchim Province

Energy consumption indicators highlight the status of energy consumption. The total final energy consumption per capita of 14 GJ is lower than the national average, yet higher than the more economically active and urbanized provinces. This is due to the usage of inefficient technologies and the huge quantity of energy consumed in the residential sector as there are limited economic activities in other sectors. The electricity consumption per capita at 149 kWh also comes far less than the national average as the grid electricity is mostly used for lighting purposes due to poor household connections. Due to lower economic status people are not able to shift to new technologies. Reliability of electricity supply in the province is also a big problem as well.

Figure 3 illustrates the flow of energy in the Sudurpashchim Province. It is quite visible that the largest shares of energy are from primary solid biomass followed by petroleum products in 2022. Most of the energy consumption is in the residential sector.

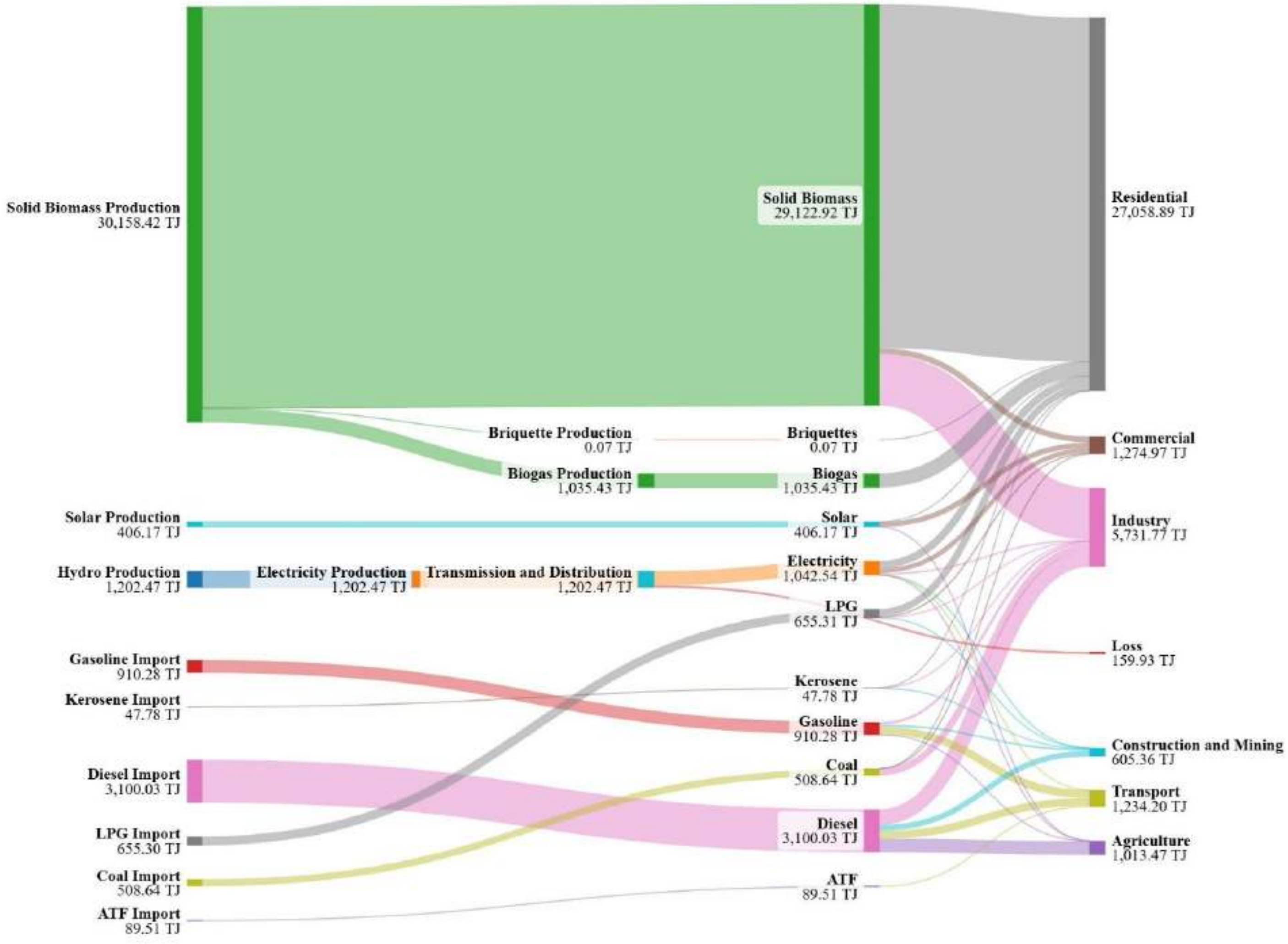


Figure 3 Energy Flow in Sudurpashchim Province (Sankey Diagram) in 2022

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 between the REF and the SED scenarios in Sudurpashchim Province was also conducted and it shows that in the REF scenario, final energy demand is expected to reach 76 PJ in 2050 from 37 PJ in 2022. In the SED scenario, the final energy demand attains 62 PJ in 2050.

Comparison between the SED and the REF scenarios indicates that per capita electricity in Sudurpashchim Province reaches 2,253 kWh in 2050 in the SED scenario compared to 667 kWh in the REF scenario. Per capita GHG emissions decline to 384 kg in 2050 in the SED scenario, whereas it will be 686 kg in the REF scenario. Installed power plant capacity requirement reaches, 2,918 MW in 2050 in the SED scenario. But it will be 734 MW in the REF scenario. Electricity demand is still low compared to other provinces, except Karnali Province.

Figure 4 indicates that in the REF scenario, lack of initiatives promoting clean and sustainable energy sources makes Sudurpashchim Province persist in its heavy dependence on biomass energy sources, coupled with an even greater reliance on imported petroleum products. This will lead to a substantial upsurge in the demand for fossil fuels by the year 2050. Besides, the viability of sustaining such a substantial demand for biomass energy from the province's forests raises serious doubts. Moreover, there are concerns about whether the economy of Sudurpashchim Province can endure the prolonged importation of such substantial quantities of fossil fuels.

The Sankey diagram shown in **Figure 5** illustrates a decrease in the dependency on solid biomass and a reduced need for importing fossil fuels to meet essential energy demands, as outlined in the SED Scenario by 2050. This shift in Nepal's energy landscape implies that the primary source of electricity demand in the Sudurpashchim Province will come from clean and renewable sources. This change not only enhances energy security but also fosters sustainability in the region.

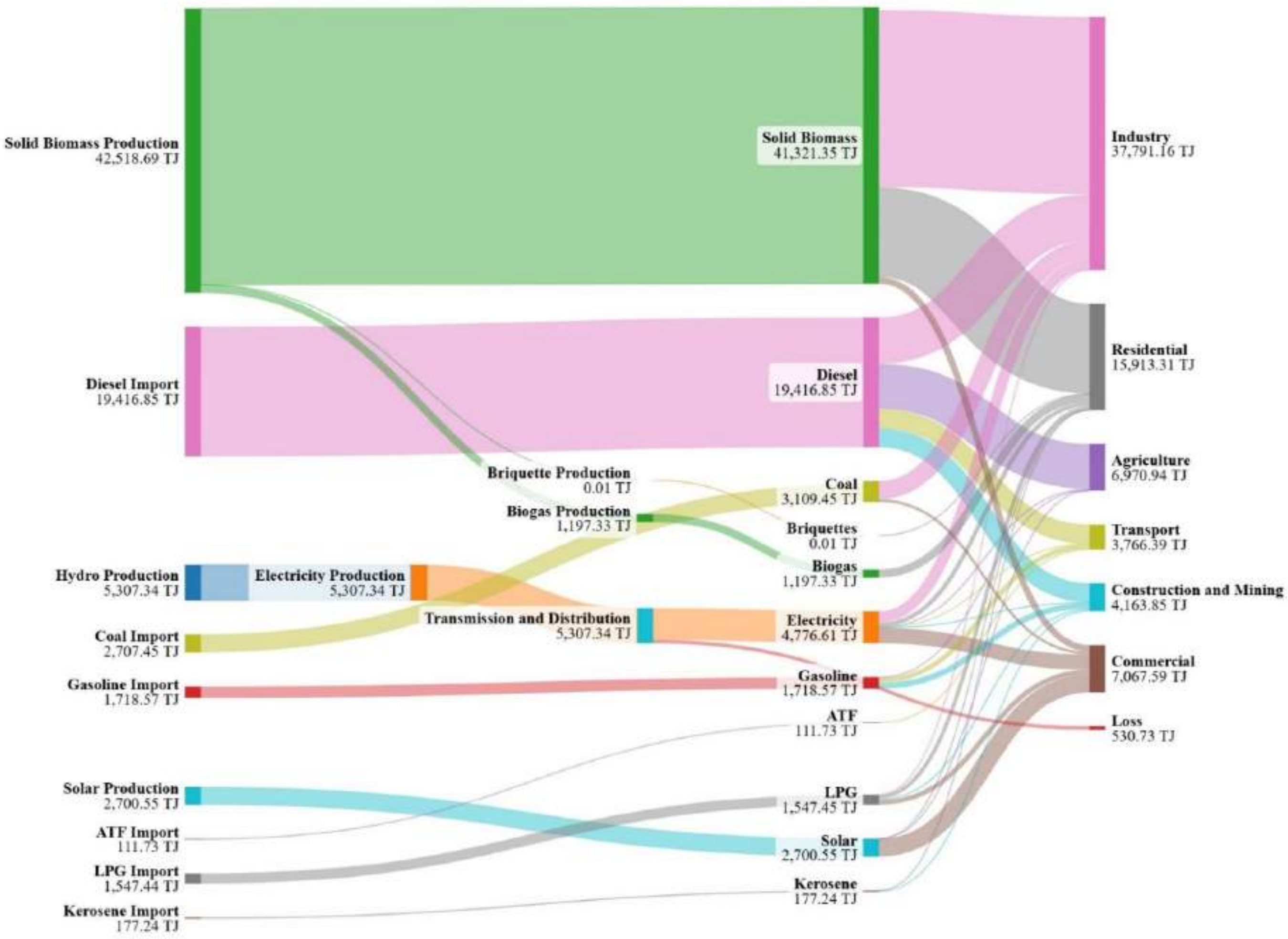


Figure 4 Sankey Diagram for Flow of Energy in Sudurpashchim Province for the Reference Economic Growth Scenario in 2050

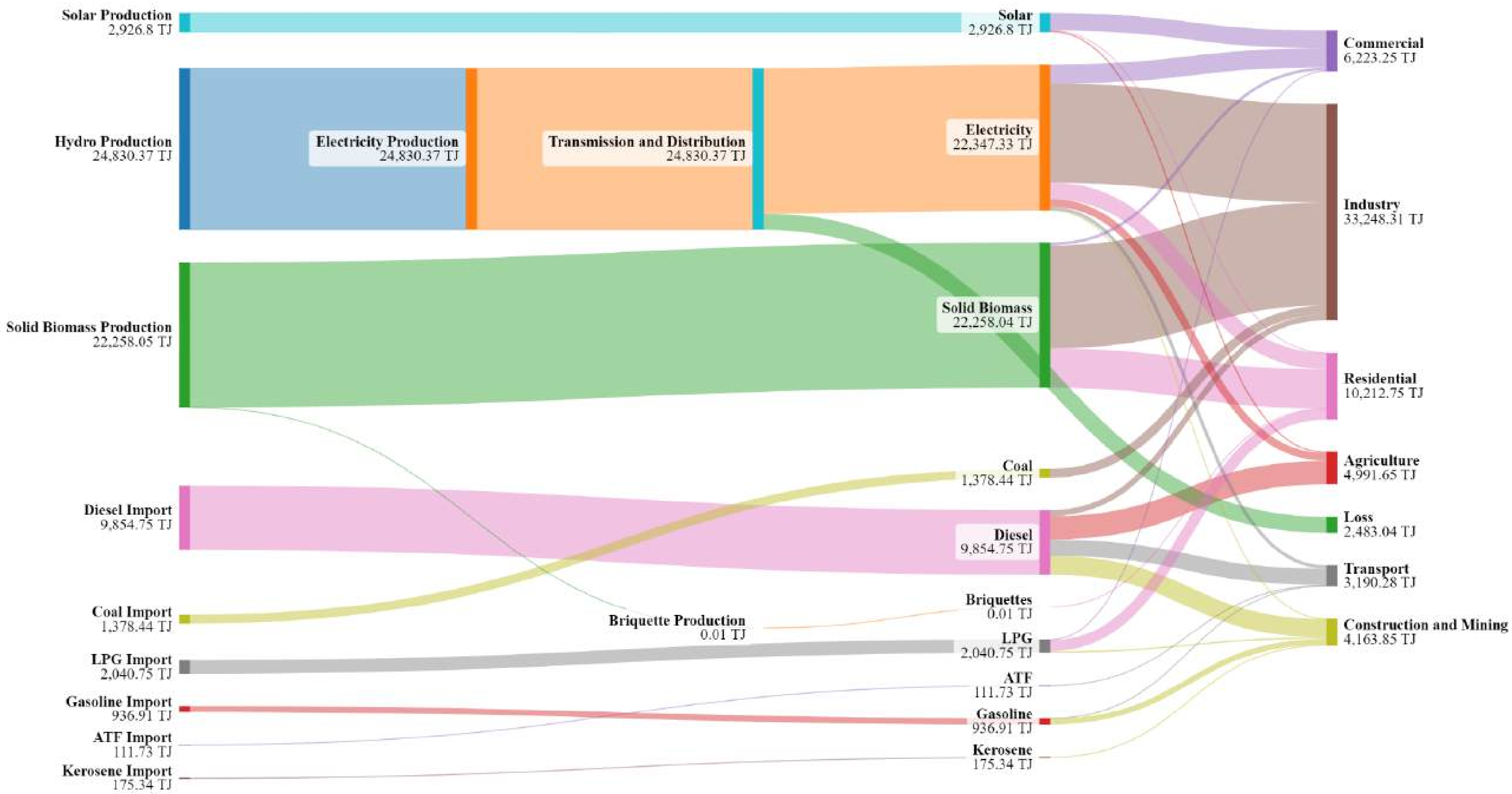


Figure 5 Sankey Diagram for Flow of Energy in Sudurpashchim Province for the Sustainable Energy Development Scenario in 2050

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Sudurpashchim Province indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and the sustainable energy development in the national context. As energy poverty is high in the province, federal and the provincial governments must focus on additional efforts for the energy transition to clean energy in Sudurpashchim Province. This study also indicates that with the core focus on energy security, reliability, and sustainability, Sudurpashchim 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 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. The most meaningful transformative change in creating a precursor to our present energy systems happened during the Industrial Revolution in England around 1750. Though fossil fuels were known before this time, the scale of their use massively increased in the nineteenth century. Before 1900 fuelwood remained the most important energy source – extensively used in cooking and heating. However, around 1900, two major developments occurred – introduction of electricity supply through electricity grids and power plants fired by coal, oil and based on hydropower (Blok et al., 2021). The adverse impacts of climate change have become severe leading to a strong global commitment to curtail GHG emissions in order to limit temperature rises to 1.5 ^{0}C by the end of twenty first century. Hence, most countries are on the pathway to transition their energy systems to cleaner energy developed from renewable sources.

The Water & Energy Commission Secretariat (WECS) is the national government authority to collect, compile, and publish energy databases. The organization has been collecting national, regional, and sector-wise energy data ever since its initiation. WECS completed Sectorial Energy Supply/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 last national energy survey carried out by WECS.

With Nepal entered into a federal system in 2015, it has been administratively divided into 7 provinces. Following federalism, the WECS also initiated collecting data on energy consumption and supply and is in the process of projecting energy demands for each province. For this purpose, WECS has already completed the project “Energy Consumption and Supply Situation in Federal System of Nepal (Koshi, Madhesh and Bagmati Provinces). The main objective of this project is to develop a database on Energy consumption, energy supply, and energy demand of the remaining four provinces viz – Gandaki, Lumbini, Karnali, and Sudurpashchim Provinces. This study pertains to the energy consumption and supply situation of the Sudurpashchim 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 causing global energy consumption to dip in a tremendous way. However, in the wake after the COVID-19 pandemic, energy production from renewables is leaping forward. Renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records (IEA, 2021). The World Energy Outlook 2021 points out that the new energy economy will be more electrified, efficient, interconnected, and clean. The report also suggests that the speed of change in energy can be countered by the stubbornness of the status quo – the main reason being uneven economic recovery from last year's Covid-induced recession. Besides, events of recent years have accentuated the cost to the global economy of an energy system highly dependent on fossil fuels. Oil, gas, and coal prices have soared to new highs with the crisis in Ukraine from February 2022 which has much more adverse impacts on oil-importing developing countries like Nepal (IRENA, 2022). The escalation of the conflict in Eastern Europe in the fourth quarter of 2022 drastically hampered 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 on the import of electricity from their neighboring countries in dry season are in a very precarious situation since most of the power plants in India and other countries are based on fossil fuels. These events forebode a catastrophic future in the world and emphasize the need to rapidly transition to clean energy from renewable sources.

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

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

World Energy Outlook (IEA, 2018)[1] emphasized that energy is of paramount importance to human society and economic activity. Its 2022 version forebodes that the combination of the Covid pandemic and the energy crisis means that those people who have gained access to electricity may lose the ability to afford electricity and around 100 million people may no longer be able to cook on clean fuels (IEA,2022). The world has seen sharp price rises in natural gas, coal, and electricity markets. The countries must act to provide modern energy services which is a necessity for eradicating poverty and reducing the divide between the rich and the poor. Besides, several empirical studies have shown that non-renewable energy is a major source of air pollution that causes severe health problems globally, especially in developing countries like Nepal.

The energy sector is responsible for almost three-quarters of the emissions. Hence, it is of utmost importance to implement solutions to climate change. Energy features are prominent in the United Nations Sustainable Development Goals (SDGs), agreed upon by almost 200 nations in 2015. Nepal, in its roadmap for achieving SDGs by 2030(NPC, 2018)' envisions a middle-income country by 2030 with vibrant, youthful middle-class population. To reach this kind of status, Nepal needs an enormous consumption of energy resources based on renewable energy and energy efficiency for sustainable energy development, and energy security in the country.

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

1.3 National Energy Scenario

The national energy consumption has been seeing growth along with growth in population and economy –a common feature of adeveloping 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 website, 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

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

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

and Madhesh and Bagmati Provinces by WECS in 2020 and 2022 also supports 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 SDG, LTS, and Second NDC. In addition to that, Nepal itself is setting its goal via targets like Electricity for All, Each house with one electric cooktop, and others.

There are strong governmental commitments of Nepal 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 path to energy transition into clean energy even though there are existing technology and economic advantage in switching over to clean energy technology such as cooking on electricity rather than on LPG and fuelwood. Analysis of household energy economics in urban areas indicates that at present it is more than 50% cheaper to cook on electricity than on LPG in Nepal (Nakarmi, 2022 - updated on 01 September 2023). Due to rising prices in the international market, import costs of petroleum products increased to NR 300 billion in 2022 compared to above NR 150 billion in 2021 – almost double in one year (NOC, 2022). These statistics amply highlight the vulnerability of economics of Nepal and energy insecurity of the country. Notwithstanding all these happenings, Nepal is already in the fifth year of National Electric Cooking Campaign (NECC) in 2024 under the AEPC and other campaign partners like NEA, NACEUN, development partners, and national NGOs. At the local levels such as Lalitpur and Terai districts, local level governments are also distributing induction cooktops in subsidy to households.

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

Nepal’s Second NDC and the Long-Term Strategy for net-zero emissions by 2045 follow the Paris Agreement of 2015, the SDG7 and other goals, and the SE4ALL program. SE4ALL targets to achieve universal access to affordable, reliable, and modern energy services, doubling the global rate of improvement in energy efficiency and increasing the share of renewable energy in the global energy mix by 2030 (UNDP, 2012; NPC, 2018). Currently as per NPHC 2021, 54% of households (HHs) use solid biomass fuels for cooking, whereas 44% of households use LPG and only 0.5% of households use electricity for cooking (NSO, 2023).

Access to electricity extends to 96% of HHs (NEA, 2022). However, the actual supply of electricity is inadequate, primarily due to lower capacity connection and reliability issues. Rural areas have access to 10% off-grid electricity that is used mainly for lighting and small electrical appliances. There was still above 12% of the population without access to electricity in Nepal (Adhikari, 2019; NEA, 2019). Solar home systems are taking a strong foothold in Nepal with the reduction of their global price per unit as well as their quick availability. However, the scope of solar energy is still limited to lighting. SDG7 targets 99% HHs access to electricity, shifting the use of fuelwood, and limiting the use of LPG by 2030 (NPC, 2018). It requires an installed capacity of 15,000 MW by 2030. To fulfill the target, the government has already started its strategic action plan focusing on the development of the energy and power sector. Nepal has prepared the implementation plan for the Second NDC to achieve the goals of hydropower development, energy access, and clean cooking.

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

1.4 Energy Supply and Demand Situation in Nepal

The overall energy consumption in Nepal reveals the dominance of the use of non-commercial energy sources. The total energy consumption of Nepal in 2022 stood at 640PJ with an annual average growth rate of 2.3% YOY. As per the energy synopsis report published by WECS, traditional energy consumption declined from 84% in 2010 to 64% in 2022 (WECS, 2023). However, the energy sources are still dominated by traditional sources (fuelwood, agricultural residues, and animal wastes). Nonetheless, there is a gradual shift to commercial energy sources (coal, petroleum products, and electricity) with an increase in the share of commercial energy from 15% in 2010 to 31% in 2021 at the national level, which recorded an increase of 12% growth per annum. There is a steady growth in renewable energy sources as well, with their share increasing from 1% in 2010 to 2% in 2021. Meanwhile, the consumption of electricity has also lately increased to 4% from 2% a decade ago. The energy consumption by fuel type in 2019/20 is shown in **Figure 1-1.**

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

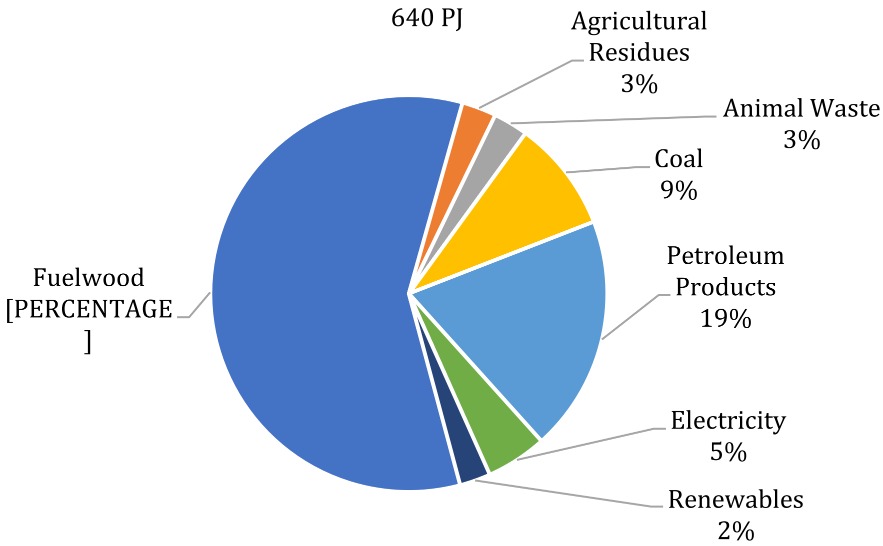
The recent provincial energy consumption and supply situation analysis completed for Koshi, Madhesh and Bagmati Provinces by WECS showed a shift in energy consumption patterns by sector (WECS, 2021b, 2021a, 2022). The detailed energy survey shows that Koshi Province consumed 74PJ with the industrial sector accounting for 45% of the energy consumption followed by the residential sectors (41%) and the two sectors together are the energy-consuming sectors. 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, 2021). In Bagmati Province, out of Total 84 PJ consumed, the highest consumption is in residential sector (42%) followed by Industrial Sector (33%). Contrastingly, in Bagmati Province, the transport sector has a large share in energy consumption of 15% which is primarily due to running of the International Airport in the Country at largest. Fuel wise, the share of petroleum product is highest in the province, wherein consumption of electricity is also very good at 10%. These differences in the energy consumption pattern of the three provinces are attributable to various factors, but majorly due to the availability and accessibility of resources as well as differences in the population, economic activities, and economic growth in the three provinces.

The major sources of energy in the residential sector are fuelwood, agricultural residues, animal waste, biogas, and other biomass sources. Hydro and solar energy sources have the potential to substitute these traditional energy sources in urban and rural households that use traditional energy sources for cooking and lighting. The industrial sector consumes coal, fuelwood, diesel, and electricity as major sources of energy with a 63% share of non-renewable energy consumption (Survey 2013). Diesel, petrol, and ATF are major fuel sources used in the transport sector with minimal use of electricity which is beginning to increase with the increase in the number of electric vehicles. The National Survey of Energy Consumption and Supply Situation in Nepal, 2013 shows fuelwood, LPG, coal, and grid electricity as the major fuel sources in the commercial sector with a 34% share of non-renewable energy. The agriculture sector mainly uses liquid fuel for water pumping and farm machinery operations, where diesel is the major fuel in use.

Apart from the gradual energy transition, Nepal is also actively working to increase access to clean energy options and increase the efficiency of energy use. The Sustainable Development Goal's target 7 (SDG-7) is directed to: i) achieving universal access to affordable, reliable, and modern energy services, ii) doubling the global rate of improvement in energy efficiency, and iii) increasing the share of renewable energy in the global energy mix by 2030 (UNDP, 2012). Nepal is also committed to achieving these targets. Nepal's SDG7 targets to expand electricity access to 99% HHs and through this replace the dependence on fuelwoods for cooking and heating. The target is to replace the use of LPG with electricity by 2030. It would require an installed capacity of 15,000 MW by 2030. To fulfill the target government has already started its strategic action plan, focusing on the development of the energy and power sector through periodic plans, and budget allocation as stated in Nationally Determined Contributions updated in December 2020.

The persisting impact of COVID-19 in Nepal over 2019-2020 led to a decline in energy consumption, mainly in production sectors. Petroleum products sales went down by 10% in 2019-20 compared to the value in 2018-19 while the electricity sale grew marginally by just 2% compared to the growth of 13% in 2018-19[3]. The growth in electricity use has risen again as COVID risk eased and industries begin to function to their capacity. Additionally, the increased access to electricity and the use of electric technologies have significantly increased the demand for electricity in the last 2 years (NEA, 2022).

[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.



(WECS 2023)

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

1.5 Provincial Situation

1.5.1 Sudurpashchim Province

Sudurpashchim Province borders the Tibetan Autonomous Region of China to the north, Karnali Province and Lumbini Province to the east, and India's Uttaranchal state to the west and Uttar Province to the south. The province covers a geographical area of 19,515.52 km^{2}which is 13.22% of the country's total area. Initially known as Province No. 7, the newly elected Provincial Assembly adopted Sudurpashchim Province as the permanent name for the province in September 2018. Godawari has been declared the capital of the province which will be replacing Dhangadhi as the provisional administrative headquarter of the province. The three major and populous cities in the province are Dhangadhi, Bhimdutta (Mahendranagar) and Tikapur, which are also major trade and commercial centers in the province.

Administratively, Sudurpashchim Province is divided into nine districts, one sub-metropolitan city, 33 municipalities, and 54 rural municipalities. The province has a population size of 2.71 million. The population density is about 136 people per square kilometer. The urban population of the province is 62.28% and the rural population is 37.72%.

The past normal pace of economic growth in the country as well as in all provinces was disturbed and badly affected by the pandemic of Covid-19 in FY 2019/20. The GDP growth rates of all provinces except Karnali and Sudurpashchim Provinces were negative. The highest impact of Covid-19 was on Bagmati Province because of being a center of economy and foreign linkages and consequently, GDP contraction was the largest in Bagmati Province. The GDP growth rate in Sudurpashchim Province was fallen by 0.44% from 6.5% in the previous fiscal year 2018/19. Even in the succeeding FY 2020/21 the GDP growth rates of all provinces and, of the country were resumed but remained below the past growth rates.

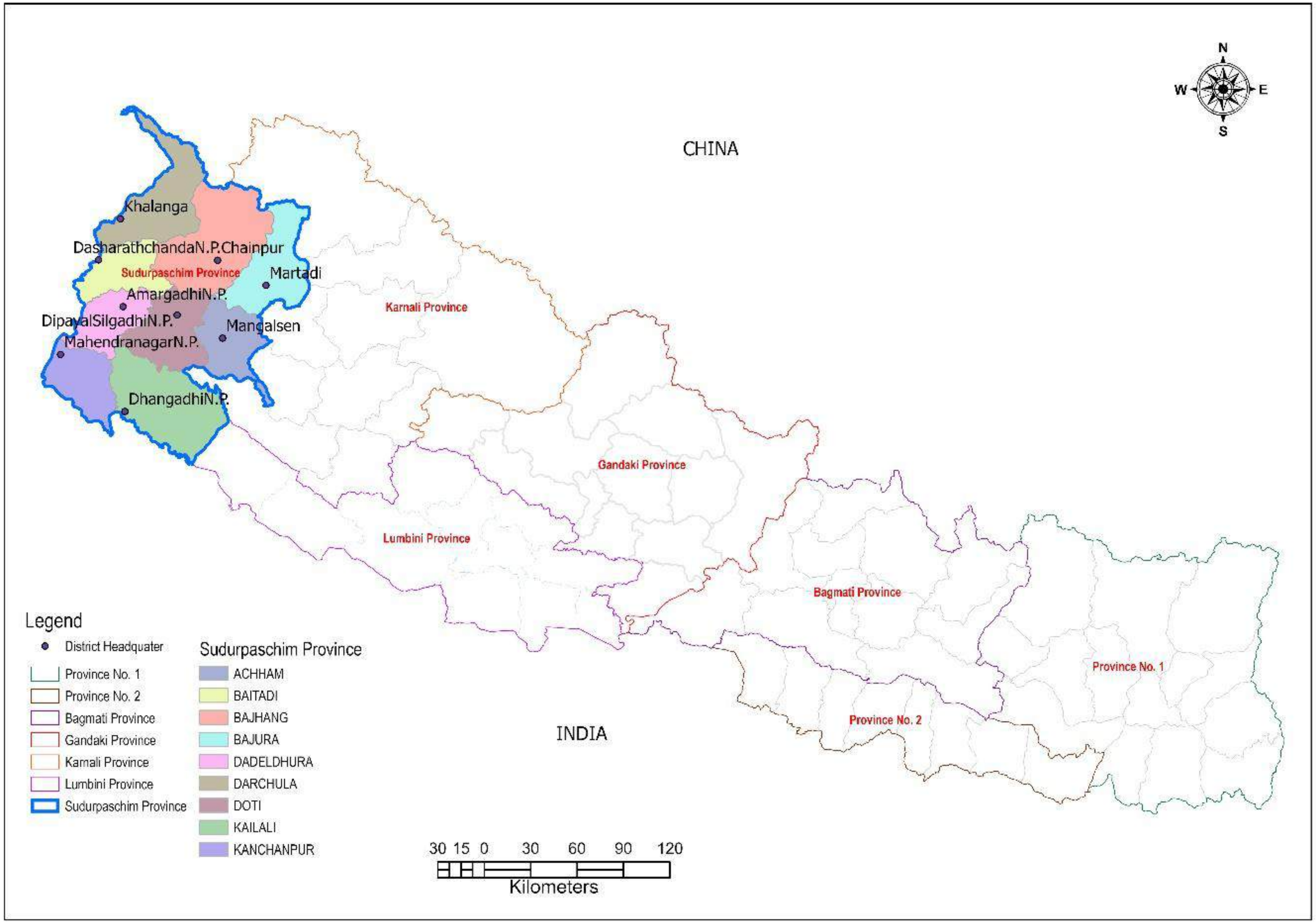
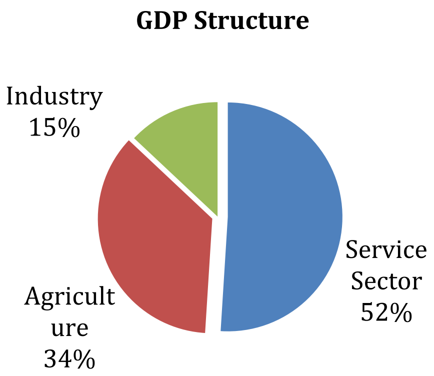


Figure 1-2: Sudurpashchim Province

The share in GDP of Sudurpashchim Province was 6.9% of Nepal in FY 2020/21, which has marginally decreased from 7% in the last FY 2019/20.

The composition of provincial GDP of Sudurpashchim in 2020/21 shows that the service sector contributed the largest share to its provincial GDP at 52%. Agriculture and industry sectors covered 34% and 15% respectively. The agriculture sector is the mainstay of the province's economy, providing a livelihood for three-fourths of the population. The past structure of provincial economy of Sudurpashchim had been changed as other provinces and the country itself had changed **(Figure 1-3).**



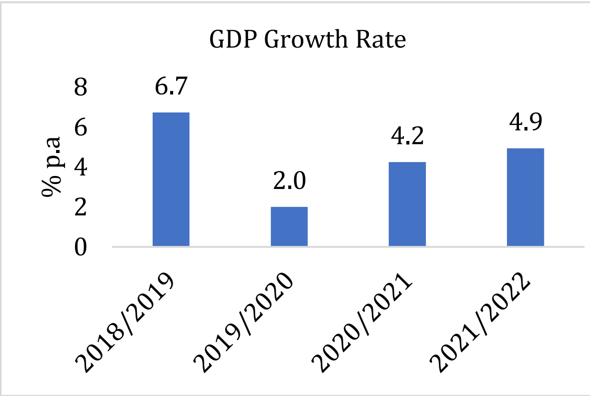


Figure 1-3: Economic Status of Sudurpashchim Province

Total expenditure of provincial government was Rs. 2,361.7 million in FY 2017/18, Rs. 112,090 million in FY 2018/19, and Rs. 156,114 million in FY 2019/20 showing its fast-rising trend. Expenditure weightages of Sudurpashchim Province in these three consecutive fiscal years were 0.11, 0.13 and 0.11 respectively. It was the least for both Sudurpashchim and Karnali Provinces in FY 2020/21.

The ratio of actual expenditure to budget disbursement in Sudurpashchim Province was 54.7%, which was almost the same as that in aggregate of all provinces (54.6%) in FY 2019/20. The ratio of capital expenditure to total expenditure in Sudurpashchim Province was 52.7% in the fiscal year 2019/20 which was less than the average of all provinces (57.2%). It was 48.6% against 50.1% in an aggregate of all provinces in 2020/21. Hence, the utilization of capital expenditure was not satisfactory in this province.

Local levels in Sudurpashchim Province had collected Rs. 23,961.6 million (13% of total revenue collected by the province).

As per NPHS 2021,81% of the population has access to grid electricity, and 16% has access to off-grid electricity through solar PVs in the province (NSO, 2023). Sudurpashchim Province generates only 51 MW of hydroelectricity (NEA, 2021). According to NEA, the highest sales of electricity sales are in the domestic sector (49%) followed by the industrial sector (17%). The loss of electricity in the province was estimated at 17% in 2021**.**

So far administrative and population situations are concerned, Sudurpashchim Province covers 13.3% of the total area with 88 local levels and 9.29% of the total population residing in this province. Forest covers 17.3% of the total land area of the country. Local road network in this province has extended till now to 5,475KM (8.5% of the national total road network). The number of schools is 4,061 (11.8% of national total). Rs. 2,512.1 billion had been invested in 41,458 industries in the province. (**Table 1-1**).

Table 1-1: Provincial Economic and Social Indicators of Sudurpashchim Province

Indicators	Nepal	Sudurpashchim	Share (%)
Administrative and population situation[1]			
No. of local level	753	88	11.7
Population (%)	100	9.29	9.3
Area (%)	100	13.3	13.3
Economic and Social Sectors			
Economic growth at consumers' prices (%)[1]	5.84	4.93	84.4
Gross Domestic Production			
Provincial contribution to GVA (at Purchasers' prices)	100	7	7.0
Per capita GDP (in US $)[1]	1,372	1,031	75.1
No. of registered industries[2]	8,656	130	1.5
No. of cottage and small industries[2]	555,776	41,458	7.5
Investment in industry (in Rs. billion)[2]	2,512.1	47.2	1.9
No. of registered companies3	283,358	5,677	2.0
hydropower production (MW)[4]	2,023		-
Forest Area (%)[5]	100	17.34	17.3
Local road network (KM)[6]	64,617	5,475	8.5
No. of Schools[7]	34,368	4,061	11.8
Financial sector[8]			
No. of branches of bank and financial institutions	11,349	828	7.3
Population per branch (no.)	2,572	3,274	127.3
Branch of Insurance companies (No.)[9]	2,905	279	9.6
provincial expenditure (in Rs. 10 million)[10]	18,883	2,297	12.2
provincial revenue (in Rs. 10 million)[10]	8,794	812	9.2

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 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.

Alternative Energy Promotion Centre (AEPC) has been promoting renewable energy technologies in Nepal with the objective to raise the living standards 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, 226 nos. of projects are implemented in Sudurpashchim Province generating 6.29 MW of electricity benefitting 68,185 nos. of rural households. The beneficiary household numbers, however, vary largely at the district levels within the province itself based on the feasibility of the technology. Bajura, Bajhang, and Achham have comparatively more beneficiary household covering 28.4%, 24.9%, and 20% of total province while Kailali (0.3%) and Kanchanpur (0%) are at the very bottom.

Specific to Sudurpashchim Province, AEPC has been able to install 1,864 nos. of improved water mills which are 16.3% of the total installations, 139,669 nos. of solar home system units which is 17.5% of the total installations, 619 nos. of institutional solar PV System generating 908.5 kWp power, 91 solar irrigation systems, and 21 solar water pumping systems (AEPC, 2021).

Addressing the need for modern renewable energy and cleaner cooking technologies to reduce household air pollution and improve the health conditions of the rural population, AEPC has promoted more than 1,612,934 cleaner and improved cooking technologies including domestic biogas, mud ICS and metallic ICS in Nepal. Out of the total, around 9% of the installation has been done in Sudurpashchim Province, i.e., 51,179 Nos. of domestic biogas plants, 87,326 mud ICS and 4,606 metallic ICS (AEPC, 2021).

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

1.6.1 Policy and Strategy Overview

- **NDC Implementation Plan 2023**

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

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

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

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

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

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

- **Second Nationally Determined Contribution, 2020**

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

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

Ministry for Electricity, Water Resources, and Irrigation (MOEWRI) released a white paper 2075 in July 2018 with the objectives to elevate hydropower and renewable energy generation in the coming decade to take the country towards the path of sustainable development. It has set the target to improve per capita electricity consumption from the current 700kWh to 1500kWh in the coming ten years. It requires the penetration of electricity in all sectors, including electrification in residential, commercial, transport, industry, and agriculture. It plans to generate 3000 MW of hydropower by 2021 and upgrade the generation capacity by 5000MW in the coming five years and by 15,000MW in 10 years. It also envisages that domestic demand will increase to 10,000 MW in the coming ten years. The government plans to generate 200MW of solar power from Madhesh province, where the hydropower potential is minimal. The white paper focuses on the optimum generation and utilization of clean energy resources, including efficiency improvement in the country.

- **Nepal Electricity Regulatory Commission Act 2074**

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

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

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

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

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

- **Low Carbon Economic Development Strategy**

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

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

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

- **Nepal's Energy Sector Vision 2050 A.D.**

Energy vision 2050 was formulated in 2013 with the vision to explore potential energy resources available in the country to meet energy demand sustainably. It envisions reducing the dependence on imported petroleum products by substituting them with indigenously available hydropower and other renewable energy resources. It identifies hydropower as the lead energy resource to meet the long-term energy demand of all sectors in the country. Electrification in all major sectors demands power capacity of 4,100 MW, 11,500 MW, and 31,000 MW by 2020, 2030, and 2050 respectively. To achieve the target, the GDP share of the energy sector should approximately be 2.4%.

- **Environment-Friendly Local Government Framework**

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

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

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

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

Key Plans, Policies, programs	Features
National Energy Efficiency Strategy, 2018	• Lists out the main activities to be carried out along with specific goals, time period as well as responsible agencies. • Focuses on following strategies: • Generate awareness about energy efficiency • Establish required policy, legal and institutional frameworks • Develop national standards for energy efficiency • Make services and production cost effective and competitive • Reduce energy import by energy conservation
National Renewable Energy Framework, 2017	• Accelerate the transition from subsidy centered model to credit-focused model along with a smart subsidy mechanism • Improve access to renewable energy
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
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.

Key Plans, Policies, programs	Features
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.

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 set targets for development in the energy sector, mainly in hydropower, solar and clean energy. It is imminent that demand for commercial energy would grow nationally as well as in provinces as well. Therefore, in this context, in accordance with the current policies and targets set by the government, the study team has looked upon clean accessible energy for all. The future energy supply plan will be based on current energy consumption as analyzed by the study itself, taking consideration of supply potential of each province first and national potential to supply energy as well as the cost effectiveness.

2 Methodology

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

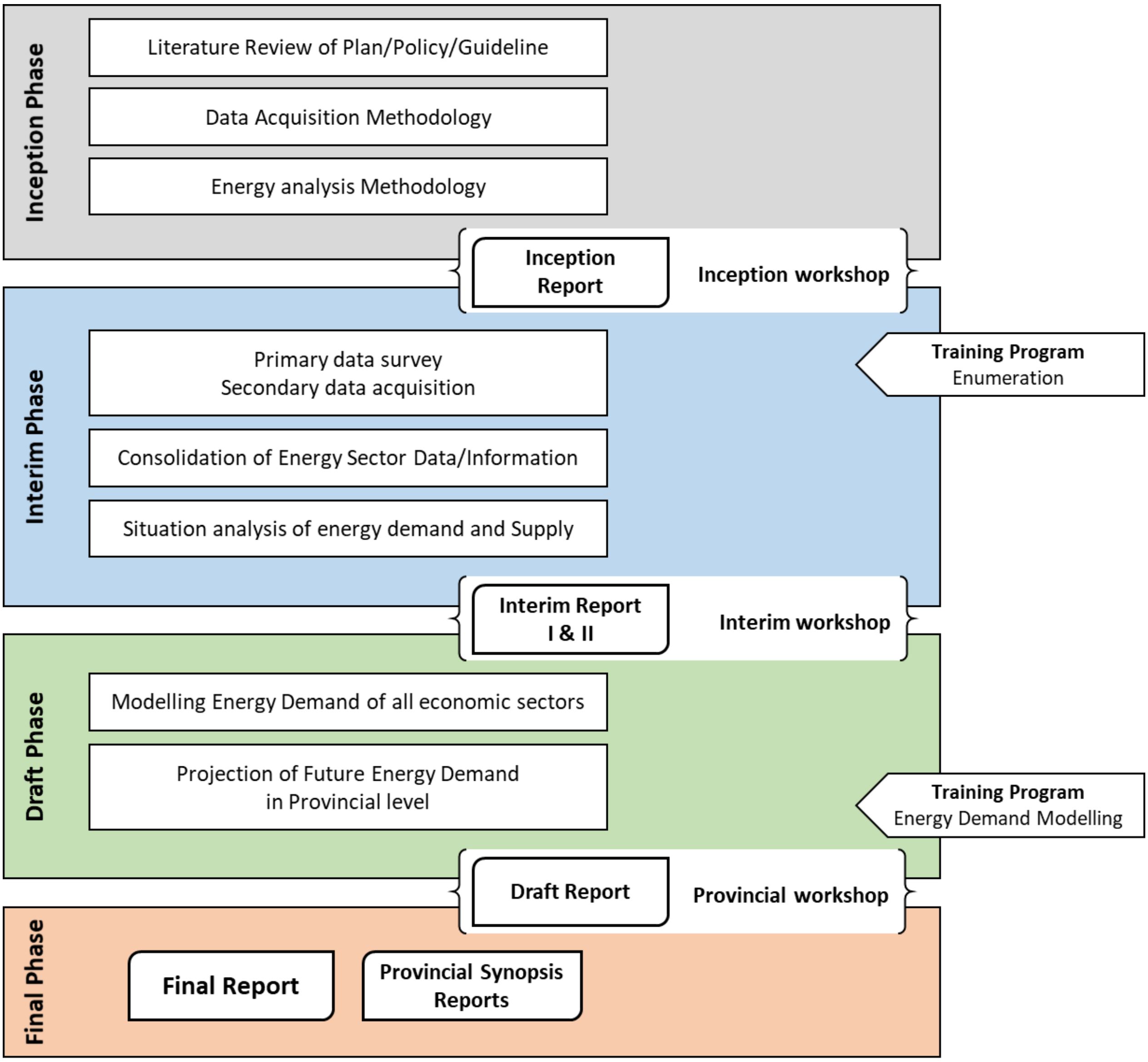


Figure 2-1: Methodological Framework

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

BOX 1: ENERGY SECTOR AND RESOURCES

State of Current Energy Demand and Changes Over Time by Sectors of Energy Uses:

a. Residential (Household) Sector
b. Industrial/Production Sector
c. Commercial/ Service Sector
d. Agricultural sector
e. Transport Sector
f. Construction and Mining Sector

Supply of Energy and Changes in Energy Supply by Source:

a. Renewable
b. Conventional renewable
c. Modern Renewable
d. Non-renewable
e. Coals
f. Petroleum
g. Natural Gas

Energy Sector Development Projects, including those undertaken in the past, relating to:

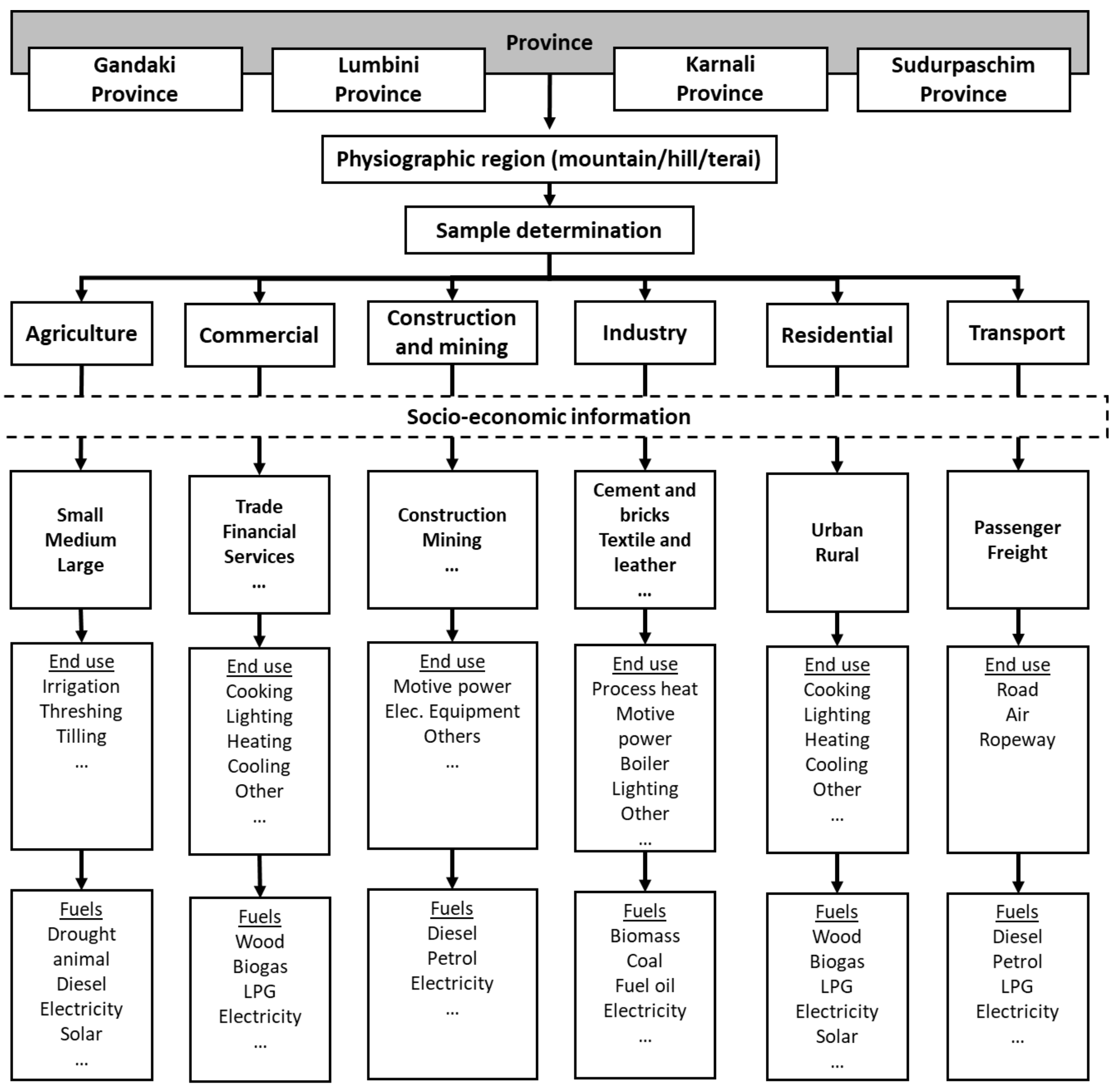
a. Hydropower
b. Micro-Hydro
c. Petroleum, Gas and Mineral Coal Exploration
d. Biomass Energy
e. Solar Energy
f. Biogas
g. Integrated Energy System

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

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

The basic disaggregation for the sample survey was bottom up for every sector for energy as well as socio- economic information. The categorization followed a framework like the given in Box 2 for Sudurpashchim Province.

BOX 2: ENERGY SECTOR STRUCTURE



2.1 Data Collection Methodology

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

Table 2-1: District Wise Population and Household Status

Mountain	**Household**	**Rural Population**	**Urban Population**	**Total Population**
Bajhang	38,368	130,882	58,141	189,023
Bajura	28,922	61,760	77,238	138,998
Darchula	29,186	88,552	46,504	135,056
Hills				
Achham	49,962	128,811	100,096	228,907
Baitadi	50,472	124,588	119,812	244,400
Dadeldhura	31,608	78,880	60,540	139,420
Doti	46,100	138,483	67,200	205,683
Terai				
Kailali	200,513	217,895	689,921	907,816
Kanchanpur	111,899	47,312	467,478	514,790
Total	587,030	1,017,163	1,686,930	2,704,093

(CBS, 2022)

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

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

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

Equation 1

Where,

P = Proportion of population (0.5)

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

N = Population size

e = Assumed Marginal error =0.05

n = Sample size

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

	Total Samples	**Response rate**
Agriculture	3431	100%
Commercial	3357	107%
Industrial	92	230%
Residential	3443	101%
Transport	1010	134%
Construction and Mining	82	91%

Data collection methodology of six sectors were adopted as follows.

- **Residential Sector:**

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

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

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

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

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

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

Equation 2

Where,

$E_{d,s}$	=	energy consumption of district d of sector s [in TJ]
$E_{f,u}$	=	energy consumption of fuel f for end use u [in local unit]
H	=	household size [person per household]
hv_f	=	heating value of fuel f [MJ per unit of fuel]
P	=	Population of sub sector x
d	=	district
s	=	sector
x	=	sub-sector
u	=	end use
f	=	fuel types

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

- **Industrial Sector:**

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

Table 2-2: Industrial Sector Categorization

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

For population size up to 750, a 33% threshold was used for the determination of sample size, and for population size more than 750, then the estimation of the sample size shall be determined with a 95% level of confidence, 5% margin error, and a5% 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 the district, subsequently giving the total energy of the province. The general formula for the approximation of energy in the industry sector is

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

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 the industrial energy consumptions in all districts.

- **Transport Sector:**

For this survey, a vehicle is considered as the primary sample unit in this sector. The sample units are motorcycles, jeeps, cars, buses, trucks, airplanes, helicopters/trains, boats, cable cars, etc. All transport sectors are broadly divided into Road Transport (Passenger and Freight), Air transport and Ropeway, Navigation, and Railways sub sector. Road, Air and Ropeway transport is further divided into public, private, corporate and government transport, and others. The transport sector is classified as **Table 2-3.**

Table 2-3: Transport Sector Categorization

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

The main uses of the transport sector are passenger services and goods carrier services. In this sector buses, cars, jeeps, vans, motorcycles, and cable cars are used for passenger services, and trucks, lorries and pickups 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 a 95% level of confidence, 5% margin error, and a 5% non-response rate.

Energy consumption for the transport sector was also calculated from a bottom-up approach. The energy data 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 transport sector is

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

Equation 4

Where,

E_p = energy consumption of province p [in TJ]

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

M_u = total distance travelled by vehicle u per year

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

V_u = Total number of vehicle u in province

s = use of vehicle (passenger, freight)

u = type of vehicle

f = fuel types

- **Commercial Sector:**

The commercial sectors represent service-providing institutions either in the form of goods or other services. For this study, the basic sample unit for this sector shall be a commercial entity. The population for a sample calculation of the commercial sector has been taken from the National Economic Census 2018 by Central Bureau of Statistics. The database, however, takes account of the institutions that are not registered as well, which can affect the approximation as their output and the value-added is not accounted for.

Since energy consumption patterns vary by commercial sector wise. The NSIC also classifies the commercial sector into different groups by the type of goods or services provided. To make representative all sectors during the survey, the commercial sector is classified 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 shall be identified from the government registration office. These numbers are considered as the population for sample size calculation. The determining sample size is proportionally distributed according to the population of different types of commercial entities as classified by National Standard Industrial Classification (NSIC).

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

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

Equation 5

Where,

$E_{d,s}$	=	energy consumption of district d of sector s [in TJ]
$E_{f,u}$	=	energy consumption of fuel f for end use u [in local unit]
$va_{x,d}$	=	value addition of the institution x in district d
hv_f	=	heating value of fuel f [MJ per unit of fuel]
VA_x	=	Total Value addition of sub sector x
d	=	district
s	=	sector
x	=	subsector
u	=	end use
f	=	fuel types

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

- **Agriculture Sector:**

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

Table 2-5: Categorization of Farm Size

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

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

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

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

Equation 6

Where,

$E_{d,s}$	=	energy consumption of district d of sector s [in TJ]
$E_{f,u}$	=	energy consumption of fuel f for end use u [in local unit]
$H_{h,d}$	=	area of holding h in district d
hv_f	=	heating value of fuel f [MJ per unit of fuel]
$A_{u,h,d,}$	=	Total area of holding H in district d using technology u
d	=	district
s	=	sector
h	=	holding (small, medium, large)
u	=	end use
f	=	fuel types

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

- **Construction and Mining Sector:**

In this sector, all major construction works such as water supply, irrigation, hydropower, crushers, high-rise building construction, road construction, bridge construction projects, and mining industries (Limestone, Coal, etc.) are the sample unit for the energy consumption survey. The district is the ultimate location for the estimation of sample size. For population size up to 750, a 33% threshold is used for the determination of sample size, and 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 demand of fuel f per year per industry
hv_f	=	heating value of fuel f [MJ per unit of fuel]
N_i	=	Total number of construction and mining industry in province
n_i	=	number of surveyed industries
i	=	type of industry
f	=	fuel types

2.2 Data Collection Tool

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

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

2.2.1 Data Collection Process

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

- The semi-structured questionnaire is coded in Open Data Kit (ODK) platform through KOBO Toolbox in Nepali and English languages which have been deployed in Enumerator's Android mobile and Tablets.
- The list of the sample HHs was provided with the address to the Enumerators in advance. GPS coordinates tracked the enumerators during the household survey through an online data survey system.
- Two-day data collection training was conducted, including a mockery and a pre-test for enumerators to make them familiar with data collection tools as well as 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 in the field were continuously monitored by the core team for quality assurance.

2.2.2 Data Quality Assurance

The following measures were applied to ensure data quality.

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

- Day-to-day feedback collected from the enumerators by the team member to assure data quality.

2.2.3 Data Analysis

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

2.2.4 Workflow of Data Collection

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

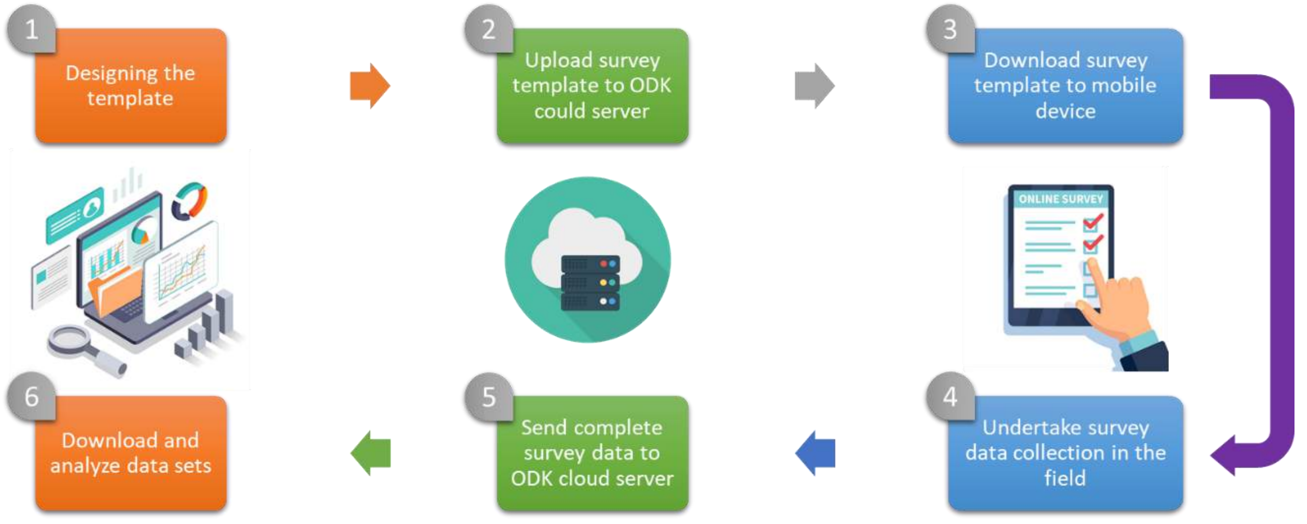


Figure 2-2: Workflow of Survey Design and Data Collection

3 Macroeconomic Analysis

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

3.1 Economic Status

The COVID-19 pandemic left an unexpected and adverse effect on the economy at both the national and the provincial levels in FY 2019/20 and also in its subsequent years of 2020/21 and 2021/22 but with were seen decreasing over time. The annual GDP growth rate at purchasers' prices of the country was reduced to -2.37% in FY 2019/20. In the same fiscal year, the annual GDP growth rate in Sudurpashchim Province was not negative as that of Gandaki and Lumbini provinces but rather positive at 2.0%. So, the adverse effects of COVID-19 on Sudurpashchim Province were relatively less in FY 2019/20 as its economy is mostly based on primitive sectors. It is also relatively less modernized. The annual GDP growth rate of the country in 2020/21 and 2021/22 were both positive at 4.25% and 5.84% respectively, as the adverse effect of COVID-19 had gradually reduced. In the meantime, GDP of Sudurpashchim Province was also positive and increasing, i.e., 4.24% and 4.93% respectively in these two consecutive years of 2020/21 and 2021/22. This decreasing adverse effect of the COVID-19 on economic activities at both levels in FY 2021/22 assisted in increasing the economic growth rates of all provinces compared to the pandemic FY 2020/21.

Figure 3-1 depicts that in the fiscal year of 2021/22, the estimated Nepal's GDP at purchasers' prices was at Rs. 4,851,625 million, out of which, Sudurpashchim Province had contributed Rs. 338,721 million (6.98%) to the national GDP. As effects of COVID -19 decreased, the estimated economic growth rate was at 5.84% in the country whereas; the estimated annual growth rate of Sudurpashchim Province was at 4.93% in the same fiscal year based on GDP at purchasers' prices.

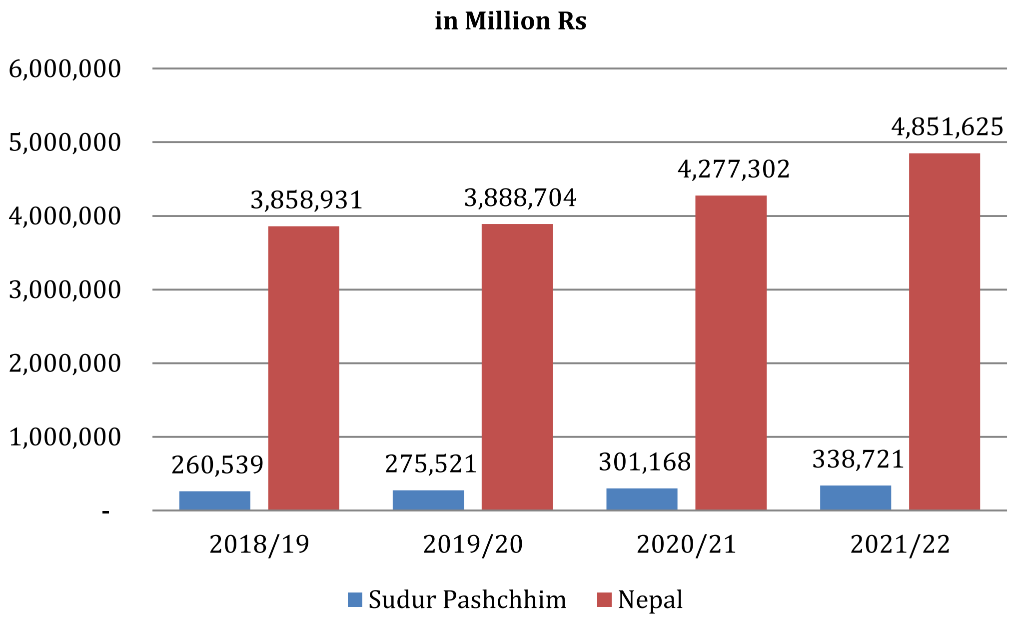


Figure 3-1: GDP at Consumers' Prices of Sudurpashchim Province and Nepal (in million NPR)

Except for the annual growth rate of the primary sector GDP (4.5%), those of both the secondary GDP (-0.1%) and the tertiary GDP (-2.6%) were negative in Sudurpashchim Province in FY 2019/20 while considering GDP at basic prices. In this province, the annual growth rate of secondary GDP rapidly increased to 4.7% in 2020/21 and 8.2% in 2021/22 compared to other sectoral GDPs. Primary sector GDP further declined in both succeeding post-COVID-19 fiscal years of 2020/21 and 2021/22 but remained positive unlike to other sectors. The adverse effect of COVID-19 on this sector still exists as growth rates of these broad sectors have not resumed to the pre-pandemic levels. Similarly, the same situation exists in tertiary sector, but its growth rate was slightly higher than that of primary sector in succeeding post COVID-19 years. (**Figure 3-2).**

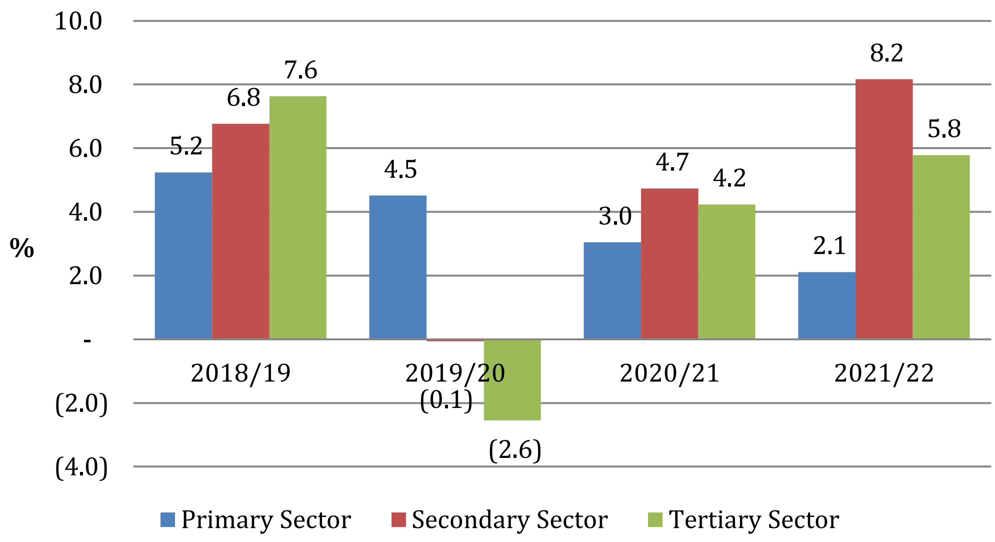


Figure 3-2: Annual Broad Sectoral Growth Rates in Sudurpashchim Province During (2018/19-2021/22)

Figure 3-3 shows that the major contributing sector to provincial GDP was the tertiary sector having around 51.8% share; whereas primary and secondary sectors contributed around 33.8% and 14.3% respectively in 2021/22 and the composition remained same in previous FYs too. The tertiary sector has gradually replaced primary and secondary sectors. The share of the secondary sector has been slowly declining, but it jumped to 8.2% in 2021/22.

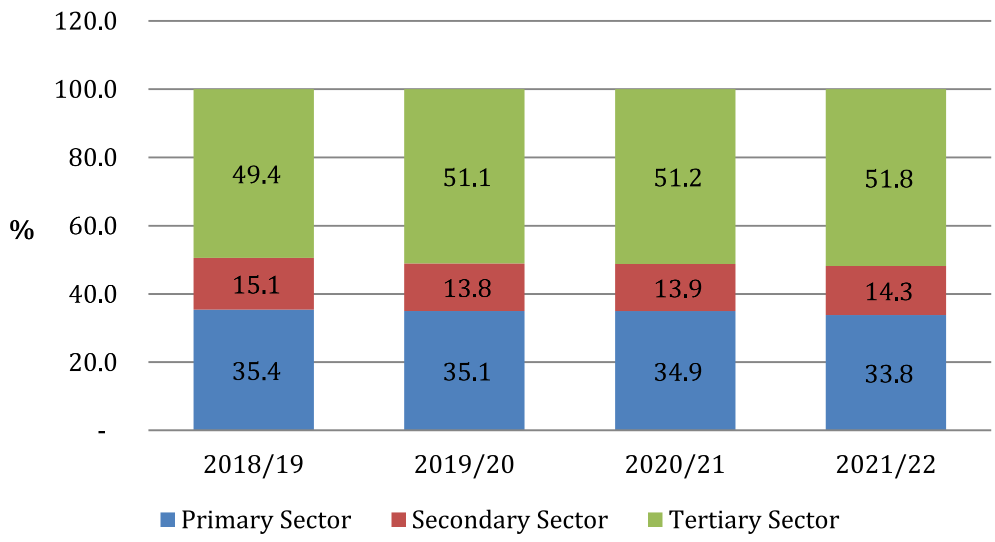


Figure 3-3: Composition of GDP at Basic Prices in Sudurpashchim Province

As presented in **Figure 3-4**, the contribution of Sudurpashchim Province to national GDP at basic prices is around 7.0% in FY 2021/22. The primary sector contributes around 9.6%, the secondary sector 7.3% and the tertiary sector 5.9% to their respective national sectoral GDP. Contributions of both provincial and all sectors are almost stable, and no remarkable changes are found. In this province, the primary sector has been contributing relatively more compared to the contributions of the other sectors.

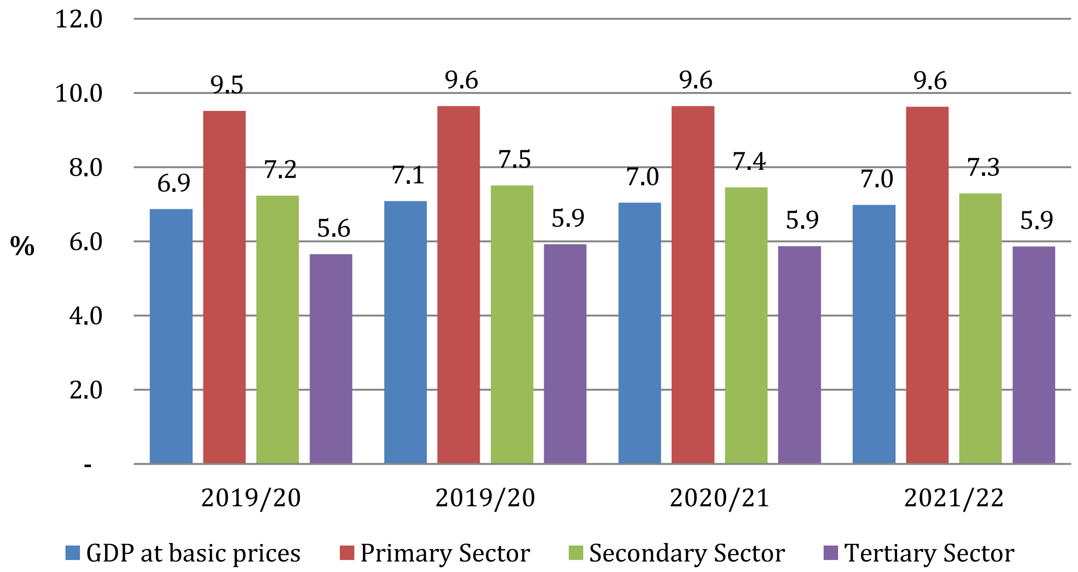


Figure 3-4: Contribution of Sudurpashchim Province to National GDP at Current Basic Prices by Sector

Per capita income in Sudurpashchim Province was estimated lower (US$ 1031) than the national per capita income (US$ 1,372) in FY 2021/22.

3.2 Public Finance

According to Financial Comptroller General Office and CBS, 2021, the revenue and expenditure of Sudurpashchim Province as a percentage of its provincial GDP was 2.7% and 7.63% respectively in FY 2020/21. Both revenue and expenditure percentages of this province were comparatively higher as the amount of its provincial GDP which was relatively low.

Table 3-1 shows that both national and provincial total expenditures increased at a faster rate. The total expenditure of Sudurpashchim Province was Rs. 14,163 million in FY 2018/19 and increased to Rs. 22,968 million in FY 2020/21, i.e., 1.6 times higher than that of FY 2018/19. The weight or provincial share of national total expenditure was slightly reduced from 12.6% in FY 2018/19 to 12.2% in 2020/21. The ratio of capital expenditure in Sudurpashchim Province was more than 50% and increasing as that at the national level.

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

FY	Total expenditure in million Rs.	Weight	Ratio of capital expenses (%)	National total expenditure in million Rs.	Ratio of capital expenses (%)
2018/19	14,163	0.126	51.07	112,090	54.4
2019/20	17,612	0.113	52.74	156,114	57.2
2020/21	22,968	0.122	54.87	188,829	59.3

Source: Financial Comptroller General, 2022

The provincial expenditure of the government of Sudurpashchim Province was Rs. 22,968 million (i.e., 12.16% of national total expenditure) in FY 2020/21 **(Table 3-2).** The total receipt of the province was Rs. 31,470 million (11.86% of national total receipts) in the same year. 73.0% of the total receipt was utilized as total expenditure but revenue contributed only 25.8% to the total receipt. Total expenditure was covered only 35.4% by revenue in this province. Grants contributed 48.9% to the total receipt. Thus, the major source of total receipt was grants.

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

	In Million Rs.			Utilization of funds	
Description	Sudurpashchim	Nepal	Share of Sudurpashchim (%)	Sudurpashchim	Nepal
Provincial expenditure	22,968	188,829	12.16	73.0	71.2
Revenue	8,122	87,944	9.24	25.8	33.2
Tax	7,809	77,009	10.14	24.8	29.0
Others	314	10,936	2.87	1.0	4.1
Other receipt including irregularities	7,944	66,410	11.96	25.2	25.0
Grants	15,404	110,348	13.96	48.9	41.6
Repayment of loan and investment	-	541	-	-	0.2
Total receipt	31,470	265,243	11.86	100.0	100.0
Provincial reserved funds (surplus +/loss-)	(8,501)	(76,415)			

Source: Financial Comptroller General, 2022

Table 3-3 shows that the provincial government of Sudurpashchim Province spent Rs. 65,041 million, out of which 55.7 % was recurrent expenditure and 44.3 % was capital expenditure in FY 2021/22.

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

	in Million Rs.		Percentage	
Province	**Sudurpashchim**	**Nepal**	**Sudurpashchim**	**Nepal**
Recurrent expenditure	3,919	35,449	55.7	54.5
Capital expenditure	3,119	28,591	44.3	44.0
Financing	-	1,000	-	1.5
Total Expenditure	7,038	65,041	100.0	100.0
expenditure weight	10.8%	100.0%		

Source: Financial Comptroller General, 2022

The total number of branches of banks and financial institutions in Sudurpashchim Province in 2021/22 (till Feb/ March 2022) was 828, which was 7.3% of the total national branches at 11,349. The number of persons per branch in Sudurpashchim was 3,274, which is higher than the national average of 2,572 during the same period. Thus, financial access to banks and financial institutions in Sudurpashchim Province is lagging in relation to the national average **(Table 3-4).**

Table 3-4: Number of Branches of Bank and Financial Institutions in Sudurpashchim Province (Feb/ March 2022)

Province	Sudurpashchim	Nepal
Commercial Bank	327	4,930
Development bank	48	1,086
Financial companies	6	257
Micro finance	447	5,076
Total	828	11,349
Share (%)	7.3	100.0
Population** (persons /branch)	3,274	2,572

Source: Nepal Rastra Bank, 2022; **CBS

3.3 Macroeconomic Modeling

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

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

If the gloomy situation as shown in the Low Growth Scenario continues in the coming twenty-eight years ahead, it will be difficult to achieve the desired goals and targets fixed in the running 15th five years plan and SDGs. However, the increasing domestic electricity generation will improve the trade deficit replacing the imported fossil fuels in future. The recent power trade agreement with India agreeing to export 1000MW in coming 10 Years will support to improve the trade deficit with India.

3.5 Variables

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

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

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

Table 3-6: List of Endogenous Variables

12. CPI	Consumer Price Index
13. DCG	Government Consumption Expenditures
14. DCP	Private Consumption Expenditures
15. DCST	Change In Stocks
16. DCTOT	Total Consumption Expenditures
17. DGFCF	Gross Fixed Capital Formation
18. DGFCFG	Government Gross Fixed Capital Formation
19. DGFCFP	Private Gross Fixed Capital Formation
20. DMGS	Imports Of Goods and Services In Real Sector
21. DTINV	Gross Capital Formation
22. DXGS	Exports Of Goods and Services In Real Sector
23. FCAB	Current Account Balance
24. FGSB	Balance on Goods and Services
25. FKFAB	Capital And Financial Account Balance
26. FMGS	Imports Of Goods and Services In External Sector
27. FOB	Overall Balance In External Sector
28. FTRB	Current Transfers Net
29. FYB	Primary Income Net
30. GCASHBAL	Budgetary Cash Balance
31. GDBOR	Domestic Borrowing
32. GDTX	Direct Taxes
33. GFAID	Foreign Aids
34. GFISCBAL	Budgetary Fiscal Balance
35. GFLOAN	Government Foreign Loans
36. GGEXP	Total Government Expenditure
37. GGOVRECI	Total Government Receipts
38. GGREV	Government Revenue
39. GINDTX	Indirect Taxes
40. GKEXP	Government Capital Expenditures
41. GNTXREV	Non-Tax Revenue
42. GOVSAV	Government Saving
43. GPR	Principal And Interest Repayment
44. GREXP	Government Regular Expenditures
45. GTRAF	Government Transfers (Government Subsidies)
46. GTXREV	Tax Revenue
47. LAG	Employment In Agriculture Sector
48. LIND	Employment In Industry Sector
49. LSERV	Employment In Service Sector
50. LTOT	Total National Employment
51. MM2	Broad Money Supply (M2)
52. PSAV	Private Savings

53. PY	Implicit GDP Deflator
54. Y	Gross National Income
55. YAG	Value Added in Agriculture Sector
56. YBP	Gross Domestic Product at Basic Prices
57. YDI	Gross National Disposable Income
58. YDIP$	Per Capita Gross National Disposable Income in US Dollar
59. YDSAV	Gross Domestic Saving
60. YIND	Value Added in Industry Sector
61. YINDTXN	Indirect Tax (Net) (Tax Less Subsidies on Products)
62. YNSAV	Gross National Saving
63. YP$	Per Capita Gross National Income in US Dollar
64. YPP	Gross Domestic Product at Producers' Prices
65. YSERV	Value Added in Services Sector

3.6 Model Simulation

The macro econometric model has been simulated based on the historical data of the period 1974/75 to 2021/22. This model has projected required macroeconomic variables for coming 28 fiscal years of period (2022/23 to 2049/50) for study on "Energy Consumption and Supply Situation in Federal System of Nepal (Provinces, namely, 4,5,6 and 7)" using the ordinary least square estimates.

3.6.1 Sources of Data and Use of Software

An economy consists of five different sectors namely, production, government, external, monetary and price, and private sectors. They are usually presented into different blocks in macro modeling exercise. The data required for the modeling exercise is of the secondary type and can be obtained from different publications of government authorities especially, MOF, CBS, NRB, and NPC and others governmental organizations as well as of the World Bank, Asian Development Bank and International Monetary Funds.

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

The System of National Accounts (SNA) 1993 has been used in the country since the fiscal year 2000/01. Therefore, the structure of national accounts has changed since the fiscal year 2000/01. The economy has been classified into 15 sectors against the traditional classifications of 9 sectors and recently has further increased to 18 sectors along with the compilation of annual GVA of seven provinces by the CBS since implementation of federal republic political system in the country. Similarly, CBS has updated the GDP by expenditure category too. Public income and expenditure pattern and balance of payment pattern have already improved. These frequent changes in compilation pattern of data have made it more complicated.

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

The Central Bureau of Statistics (CBS) publishes only the government and private gross fixed capital formation. Sectoral gross fixed capital formation is not published. Sectoral gross fixed capital formations for the period of 1974/75 to 2021/22 have been estimated based on its annual control totals published by CBS. Sectoral and national ICOR used in some last midterm Plans published by the National Planning Commission (NPC) have also been used as basis for estimation of sectoral gross fixed capital formation for last few years. That's why data on sectoral gross fixed capital formation is weak. Population is calculated using figures from the decennial census of CBS. For the intermediate years interpolation method with compound growth rate has been used. Similarly, Indian CPI has been taken from the website of the Reserve Bank of India.

The employment database is also weak because the employment data in different sources are widely different and inconsistent. So, the sectoral employment has been estimated using the interpolation and extrapolation of the sectoral employment growth rates based on the economically active population published in Population Census Reports of 2071, 2081, 2091, 2001, 2011 and 2021 since the employment data published in Nepal Labor Force Surveys Reports and in National Economic Census Reports are in unexpectedly low side especially for last decade. No doubt, employment was low due to the increasing foreign employment and political instability during the last decade, but it is difficult to expect to that extent. In fact, this method of interpolation and extrapolation based on inter censuses gives us linear growth rate of the employment of respective sectors, which can hardly be realistic but, it is bound to accept it since there is no other option.

Software used

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 laborers for foreign employment is increasing.

Other Exogenous Variables:

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

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

In Percent

Indicators	2011-2020	2021-2030	2031-2040	2041-2050	2023-2050
EXGRATE1	4.70	1.90	1.80	1.50	1.70
FXGS1	2.10	4.10	1.40	1.20	1.60
GFGRANT1	(12.0)	6.70	1.90	1.00	2.70
GFI_N1	14.30	1.20	2.30	2.00	2.20
INDCPI1	6.20	5.60	4.60	4.02	4.70
POP1	1.00	1.10	1.10	1.00	1.10

- **Reference Scenario**

It is assumed that the country's economic situation will gradually be improved in future. Most of the political parties have thought that the political issue has been solved for a while and economic transformation is, now, the important task. So, the government has concentrated solely on the economic prosperity of the country.

The government has decided to develop the agriculture sector encouraging and mobilizing the returnees from overseas employment by providing them economic incentives and skill training to be self-employed in agriculture sector. Some of them have returned with skills and technical know-how too. They have invested and are operating 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 also have 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 Scenarios 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 the 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

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%

(Calculations)

Three scenarios of provincial gross values added by industrial division for each concerned province have been forecasted based on above mentioned 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, 2022; Worldbank, 2013; CBS, 2012). 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 basic assumptions taken for scenario development of each of the energy sectors.

Table 4-2. Energy Sector Dependent Variables

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

In the residential sector, which is a non-economic sector – in a viewpoint that there is no measurable economic output, the consumer behavior is major affecting parameter i.e. the population is the driving factor. Meanwhile 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 Modeling 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 therefore, 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 4-3.** 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 consumption analysis. From here, energy scenarios have been developed until 2050[4], 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 for energy demand projection as it is one of the robust, freely available energy demand analysis software. Secondly, the 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.

[4] 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.

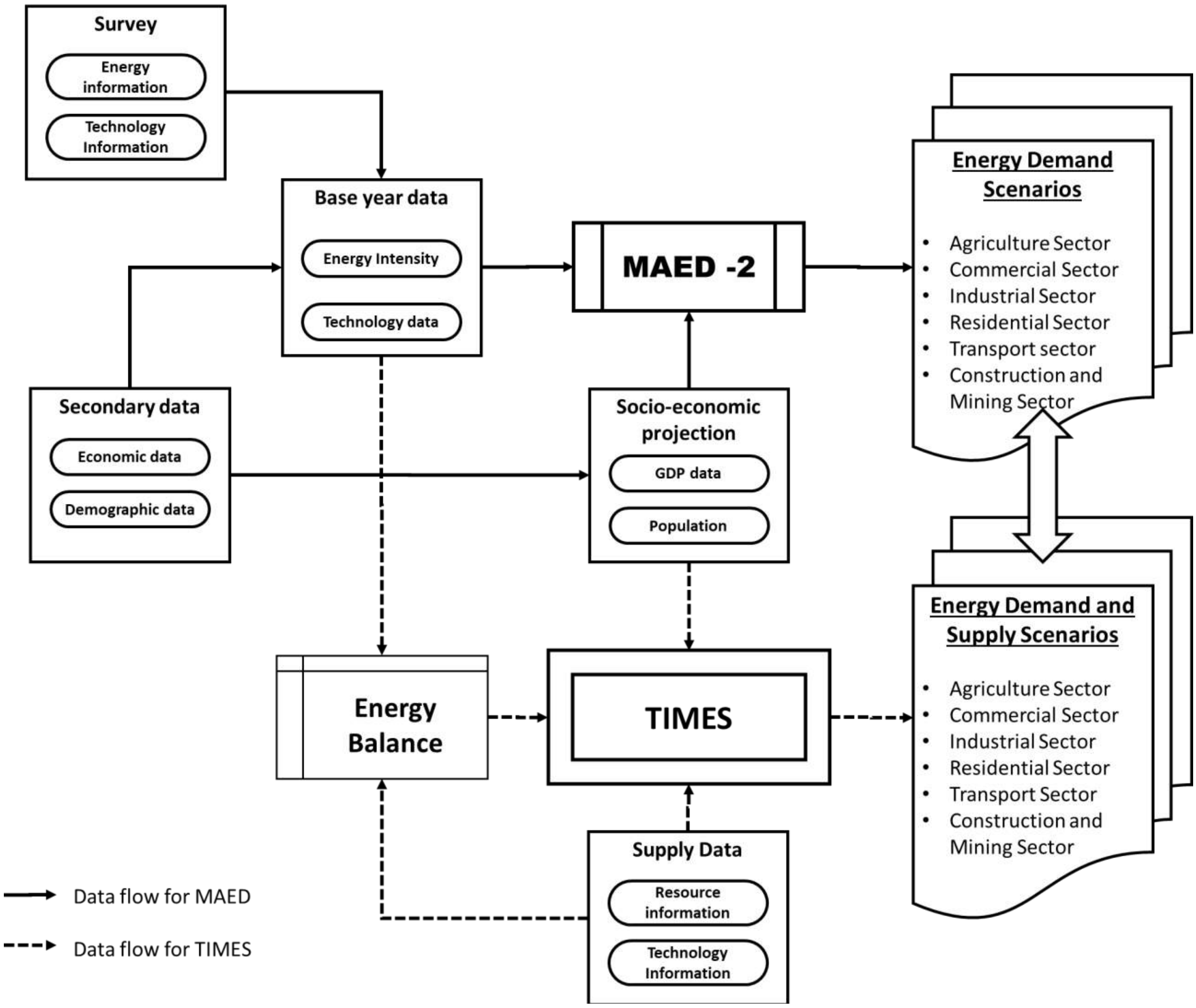


Figure 4-1: Methodological Framework of Projection in MAED and TIMES

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

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

4.4 Energy Demand Projection

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

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

4.4.1 Model for Analysis of Energy Demand (MAED)

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

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

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

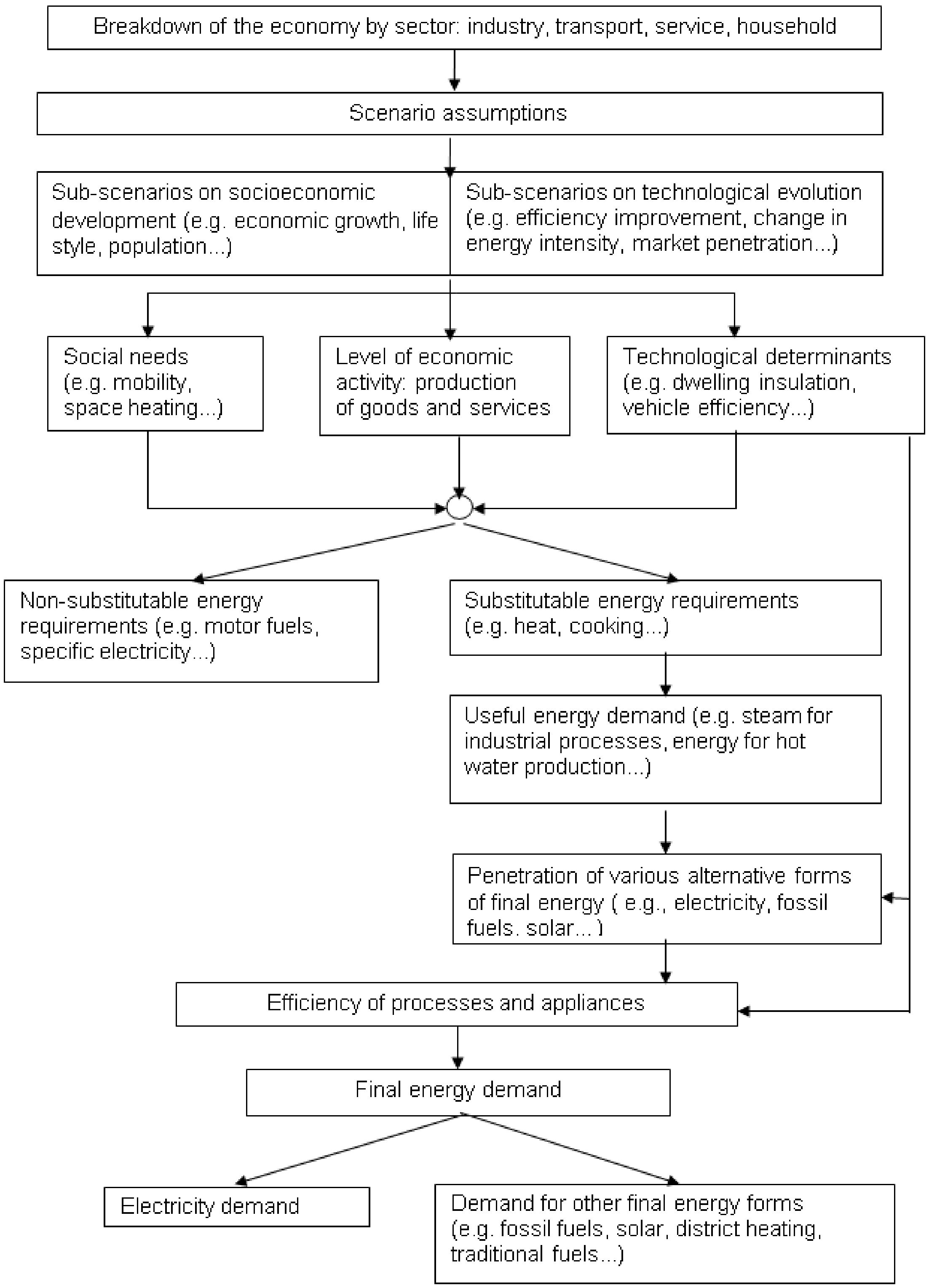


Figure 4-2: Scheme used to Project Useful and Final Energy Demand in Module 1 of MAED

4.5 Energy Supply Analysis

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

4.5.1 The Integrated MARKAL-EFOM System (TIMES)

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

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

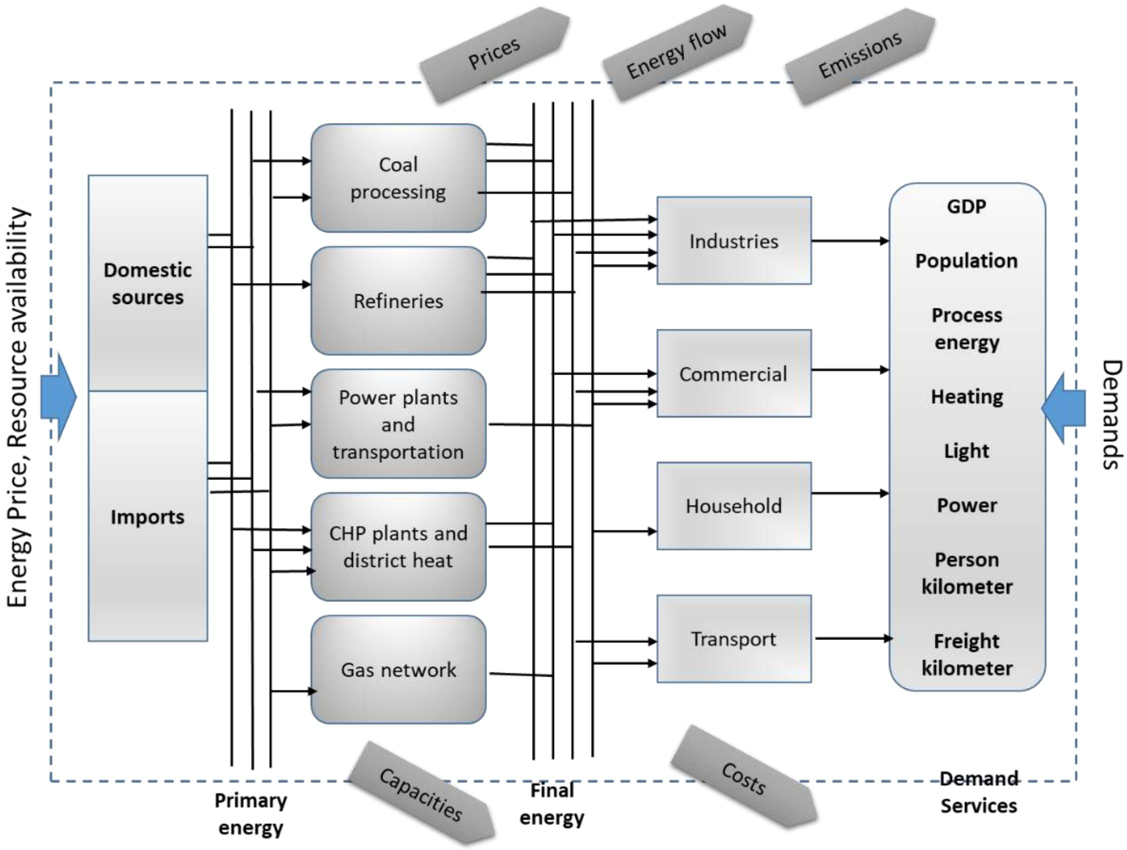


Figure 4-3: Structure of TIMES Framework

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

- *Energy carriers* encompass all the energy forms in the energy system, such as petroleum, electricity, or fuelwood.

- *Demands* are the end-use demands of energy services, such as residential lighting or intercity freight transport demands.
- *Resource technologies* are the means by which energy enters or leaves the system, other than by end use consumption.
- *Process technologies* convert one energy carrier into another, excluding load-dependent ones such as electricity.
- *Conversion technologies* convert an energy carrier into electricity and/or district-heat.
- *Demand technologies* consume an energy carrier to meet end-use demands.
- *Emissions* encompass the environmental impacts of the energy system.

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

TIMES Model Run and Solutions

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

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

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

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

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

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

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

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

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

Equation 4.1

Where, X = vector of all decision variables

I = number of demand categories

CAP = capacities of end-use technologies

DM = exogenous demands to be satisfied

B = coefficient of other constraints

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

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

5 Energy Supply Situation

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

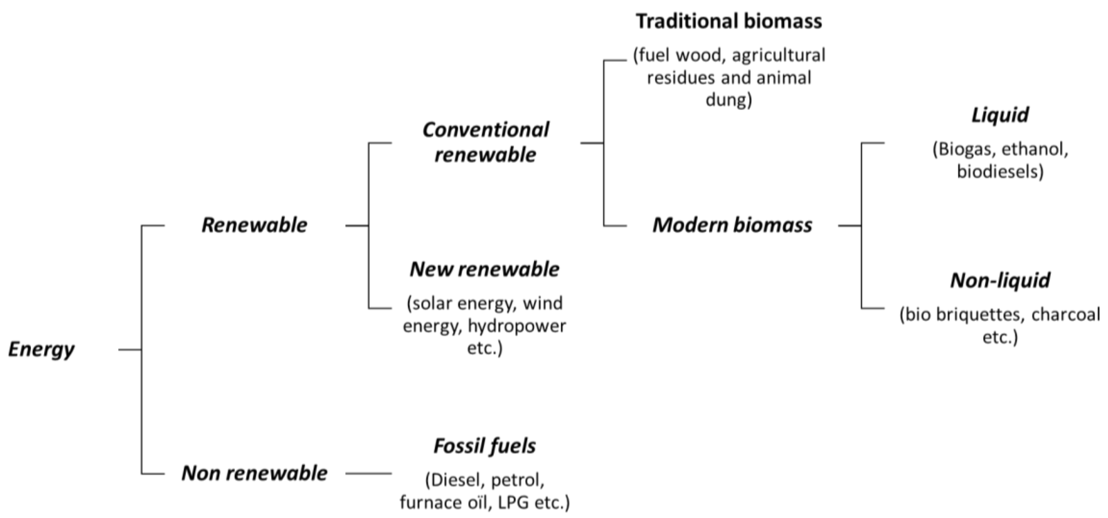


Figure 5-1. Energy Classification for Nepal[5]

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

5.1 Solid Biomass

Sudurpashchim Province of Nepal is blessed by nature with lush of forests in terai, dun valleys like Jogbudha, mid hills, and high hills. As compared to other provinces of Nepal, this province has more forest area per person. In addition, there is good sunlight, enough water in the watersheds of Karnali and Mahakali rivers, and abundant alluvial soils. Although deforested to some level, there is still good forest cover throughout the province. But urbanization and agriculture have encroached on good forest lands which is prominent especially in Kailali and Kanchanpur districts. Similarly, human pressure for fuelwood in the past has led to overcutting of trees. Despite this, Sudurpashchim Province still has good potential for forest management and production with its rich soil and history of community forestry. These forests have very high energy potential for the locals who are poor and depend on them as a cheap source of bio energy.

[5] As per Terms of Reference

Forests in Sudurpashchim Province

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

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

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

Subalpine forests occur between 3,000 – 4,100 meters and are mainly comprised of small and generally ill-formed trees of *Abies spectabilis*, *Picea smithiana*, *Betulautilis*, and *Rhododendron* spp. Alpine scrub vegetation occurs between the treeline (around 4,000 meters) and snowline (around 5,500 meters). The table below shows the forest area and major species of Sudurpashchim Province.

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

SN	physiographic zone	altitude (m)	districts	forest area (ha)	major species	Total Stem volume (m3)	growth Growth rate %
1.	Terai	500	Kailali and Kanchanpur	247,773	sal, sisoo, khair, asna	41,378,091	medium
2.	Middle mountain	500-3,000	Dadeldhura, Baitadi, Doti, Achham	448,948	chima-castanopsis, pinus, oak, alnus	50,102,597	medium
3.	Higher mountain	3,000-5,000	Bajhang, Bajura, Darchula	387,066	rhododendron, abies, acer, betula, picea	60,962,895	slow

(DFO Achham, 2074, DFO Bajura, 2070, DFO Darchula, 2075, DFO Kailali, 2075,DFO Kanchanpur, 2074, DFO Doti, 2075, DoF 2019)

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

5.1.1 Forest management in Sudurpashchim Province

The Shuklaphanta National Park and Khaptad National Park 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. Most prominent forest management in

Sudurpashchim Province is community forests, although there are limited Collaborative Forest Management and block forests managed by the government.

Area of forests in Sudurpashchim Province under community forest management is given in **Table 5-2.** The table shows that 294,366 ha area is handed over to 2,966 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. Community Forests and Areas in Sudurpashchim Province(ha)

SN	Districts	No of UG	Area Managed
1	Kailali	582	64,345
2	Kanchanpur	136	19,329
3	Dadeldhura	473	37,127
4	Baitadi	315	25,899
5	Doti	397	77,140
6	Achham	406	41,253
7	Darchula	164	6,616
8	Bajhang	275	10,928
9	Bajura	218	11,729
	Total	**2,966**	**2,94,366**

(DFO Achham, 2074, DFO Bajura, 2070, DFO Darchula, 2075, DFO Kailali, 2075,DFO Kanchanpur, 2074, DFO Doti, 2075, DoF 2019)

5.1.2 Wood as Fuel

Biomass, the total of non-fossil organic material derived from biological sources, is the most important source of renewable energy in the world (Lauri et al. 2014). It accounts for 35 % of primary energy consumption in developing countries and 14 % of the final energy consumption, globally (Parrika 2004; Demirbas et al. 2009; Panwar et al. 2011). Fuelwood is the main source of energy in rural Nepal. It accounted for 70% and biomass for 92% of Nepal's total energy consumption. The main use of Nepal’s forests is to provide biomass to satisfy the energy needs of rural and remote regions. Fuelwood is used for several purposes like cooking, heating, lighting, etc. Historically, Nepal’s rural populations have been meeting their energy needs from traditional sources like fuel-wood and other bio-mass resources (AEPC, 2000). Most of the fuelwood has been reported to be derived from forests with some trees outside the forest and trees growing in homeland and agricultural areas. Forests provide about 81 percent of the total fuel requirements of Nepal. However, the average annual production of fuelwood constitutes only 31 percent of demand. Agricultural residues contribute about 51 percent and cattle dung accounts for the rest (18 percent) (WECS, 1996). Following its national policy, Nepal gives emphasis to alternative and other renewable energy sources that aim at reducing dependence on forest products and animal dung (FAO 2019)[6]. The demand for fuelwood in the country has rapidly increased due to population growth in the past and had in resulted tremendous pressure on existing forests. Local communities bring hundreds of cycle loads of fuelwood to their villages from forests in rural areas. But, due to the migration of the population into town, the rural population has decreased in recent years.

[6]http://www.fao.org/3/ae154e/ ae154e06.htm

5.1.3 Effect of Fuelwood Collection to Forest

In past decades, because of the increasing population, the area under agriculture expanded, and forests shrank. The forest area in the Terai declined by 16,500 ha in the years from 2001 to 2010 and by 32,000 ha in the 19 years from 1991 to 2010. In Kailali district alone, the encroached forest land is 22,115 ha. The average annual rate of decrease in forest cover was 0.44% during the last nine years from 2001 to 2010 and was 0.40% during the last 19 years from 1991 to 2010/11. The annual rate of deforestation in all 20 Terai districts was 0.06%, excluding protected areas (FRA/DFRS, 2014). In Kailali and Kanchanpur districts, cultivable land increased at the expense of forest lands. On the other hand, due to poverty, the demand for fuelwood increased despite the rapid growth in the commercial energy sector. Fuelwood is practically free if people afford time for collection. A large quantity of fuelwood is being collected from community and government managed forests by the locals. In present context, forests, and forest conditions in different districts of Sudurpashchim Province are in **Table 5-3**.

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

Districts	Area in ha	Fuelwood produced in chatta
Kailali	197,309	950
Kanchanpur	50,464	4,575
Dadeldhura	111,399	1,336
Baitadi	92,107	
Doti	141,260	1,839
Achham	104,182	11,361
Darchula	106,585	5,040
Bajhang	147,234	
Bajura	133,247	1,764
Total	**977,202**	**26,865**

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

(DFO Achham, 2074, DFO Bajura, 2070, DFO Darchula, 2075, DFO Kailali, 2075,DFO Kanchanpur, 2074, DFO Doti, 2075, DoF 2019)

5.1.4 National Demand and Supply Situation

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

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

- **Fuelwood from Community Based Forests**

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

5.1.5 Potential Increment

Sustainable management of forests in Nepal could not only increase and stabilize the supply of forest products, but also help in contributing to livelihood of the people involved in 17, 685 community forests, and 2.18 million households are involved in community forest management (DoF, 2012) and collaborative forest management. The demand and supply of forest products depend not only on biophysical factors inherent in different ecological regions of Nepal but also on the policy regimes perused and implemented by the Government of Nepal (MFSC 2013). **Table 5-4** provides the fuelwood collection in the Sudurpashchim Province.

Table 5-4. Forest Area and Potential Fuelwood Production in Current

	Forest Area	Accessible forest area	Fuelwood Production/year in m^3	Fuelwood Production/year in kilo ton
Kailali	197,309	197,309	597,065	424.5
Kanchanpur	50,464	50,464	152,706	108.5
Dadeldhura	111,399	100,259	225,270	160.2
Baitadi	92,107	82,896	186,258	132.4
Doti	141,260	127,134	285,655	203.1
Achham	104,182	93,764	210,676	149.8
Darchula	106,585	74,610	304,183	216.2
Bajhang	147,234	103,064	420,191	298.7
Bajura	133,247	93,273	380,273	270.4
Total			**2,762,278**	**1,963.9**

(DFO Achham, 2074, DFO Bajura, 2070, DFO Darchula, 2075, DFO Kailali, 2075,DFO Kanchanpur, 2074, DFO Doti, 2075, DoF 2019)

Thus, annual fuelwood from the whole Sudurpashchim Province is 2,762,278 m^3 (This is a harvestable quantity). This volume accounts for 11 categories, 10 defined species, and 1 other (miscellaneous). And to classify timber production as per species, the proportion of stem volume of each species is multiplied to 2,762,278 m^3. Thus, obtained value is converted to the kilogram and or tone using wood density (average 1 m^3 =711 kg) and totaled to final fuelwood to 1,963.9kilo tons.

5.2 Biogas in Sudurpashchim Province

- **Livestock in the Sudurpashchim Province**

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

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

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

District	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Achham	43,989	35,322	3,085	114,431	394	87,201	313
Baitadi	124,533	50,071	504	129,803	658	29,496	234
Bajhang	129,857	30,966	26,452	82,558	2,046	49,539	409
Bajura	85,002	21,962	19,672	77,718	1,604	54,691	432
Dadeldhura	89,943	21,635	425	141,919	1,249	66,284	205
Darchula	68,474	30,423	22,861	68,332	552	37,348	220
Doti	109,539	48,102	662	118,896	2,471	127,770	174
Kailali	216,295	158,695	14,267	141,293	24,613	1,541,163	7,431
Kanchanpur	152,601	112,923	4,553	133,340	14,109	1,033,936	4,200
Total	**1,020,233**	**510,099**	**92,481**	**1,008,290**	**47,696**	**3,027,428**	**13,618**

(Source: MoALD, 2022)

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

Table 5-6. Dung production in Sudurpashchim Province

District	Cattle	Buffaloes	Dung produced from cattle tons/ year	Dung produced from buffalo tons/ year	Total dung production tons/Year
Achham	43,989	35,322	160,560	193,388	353,948
Baitadi	124,533	50,071	454,545	274,139	728,684
Bajhang	129,857	30,966	473,978	169,539	643,517
Bajura	85,002	21,962	310,257	120,242	430,499

Dadeldhura	89,943	21,635	328,292	118,452	446,744
Darchula	68,474	30,423	249,930	166,566	416,496
Doti	109,539	48,102	399,817	263,358	663,176
Kailali	216,295	158,695	789,477	868,855	1,658,332
Kanchanpur	152,601	112,923	556,994	618,253	1,175,247
Total	**1,020,233**	**510,099**	**3,723,850**	**2,792,792**	**6,516,642**

(Source: MoALD, 2022 and calculations)

5.2.1 Potential of Biogas Energy Production Per Year

The estimation of potential biogas production in Sudurpashchim Province is done considering the biogas production factor as 0.036 cubic meter per kg of dung (WECS, 2010), and 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 energy using the 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 production in 2020/2021

District	Total dung production "000" tons/Year	Biogas in "000" cubic meter	Energy in "000" Gj per year	Potential percentage	Potential in 000 Gj
Achham	354	12.742	254.84	0.75	191.13
Baitadi	729	26.233	524.65	0.75	393.49
Bajhang	644	23.167	463.33	0.5	231.67
Bajura	430	15.498	309.96	0.5	154.98
Dadeldhura	447	16.083	321.66	0.75	241.24
Darchula	416	14.994	299.88	0.5	149.94
Doti	663	23.874	477.49	0.75	358.11
Kailali	1,658	59.700	1,194.00	1	1,194.00
Kanchanpur	1,175	42.309	846.18	1	846.18
Total	**6,517**	**234.599**	**4,691.98**		**3,760.74**

(Source: MoALD, 2022 and calculations)

Temperature plays a significant role in the production and efficiency of biogas technology. 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 3 high hill districts, 75% for 4 mid hill districts and 100% for 2 Terai districts. As per **Table 4-7**, production of biogas for Sudurpashchim Province is 3,760 thousand GJ per year.

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

Waste-to-energy (W2E) generation is one of the promising sustainable alternatives for biogas and electricity generation from discarded organic waste materials and by-products from various commercial/ industrial activities and municipal waste. It is also a solid alternative to solid waste management since these intend to recover energy from the waste thereby reducing the quantity of waste sent to landfill sites. It is environmentally beneficial by nature as it also helps in reducing the amount of greenhouse gases emissions from landfill sites as well as minimizing 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 the quantity of waste is economically available for operating large-scale biogas production such that it can be used for bottling, pipeline, electricity generation, or other end use.

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

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

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

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

District	District population (2078)	Total Commercial /Industrial Waste (tons/day)	Total Organic Municipal Waste (tons/day)	Total Organic Waste Production (tons/day)	Total Biogas Yield (cum/day)	Total Organic Waste Production “000” tons/Year	Biogas in “000” cubic meter	Energy in “000” GJ per year
Achham*	2,29,816	1.03	6.98	8.00	445.25	2.92	162.52	3,250.33
Baitadi*	2,44,400	1.09	7.42	8.51	473.51	3.11	172.83	3,456.59
Bajhang*	1,89,097	0.84	5.74	6.58	366.36	2.40	133.72	2,674.43
Bajura*	1,38,998	0.62	4.22	4.84	269.30	1.77	98.29	1,965.87
Dadeldhura*	1,39,420	0.62	4.23	4.85	270.12	1.77	98.59	1,971.84
Darchula*	1,35,056	0.60	4.10	4.70	261.66	1.72	95.51	1,910.12
Doti*	2,05,683	0.92	6.24	7.16	398.49	2.61	145.45	2,909.01
Kailali **	9,11,155	2.48	9.90	12.38	694.40	4.52	253.46	5,069.12
Kanchanpur **	5,17,645	3.21	25.80	29.01	1,601.60	10.59	584.58	11,691.68
Total	**2,711,270**	**11.41**	**74.63**	**86.04**	**4,780.68**	**31.40**	**1,744.95**	**34,899.00**

(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 cow farms, buffalo farms, poultry farms, pig farms, sugar industry, liquor industry, vegetable markets slaughterhouses, hospitals, and residential schools.

Organic municipal waste is the segregated part of the total municipal waste which excludes non-organic dumping waste.

The W2E potential for all the districts other than Kailali and Kanchanpur has been calculated based on the proportionating population density with reference to Kailali and Kanchanpur since no field studies have been conducted in these districts yet.

Since technically feasible and financially viable W2E projects demand an uninterruptable and sizable quantity of waste economically available for the operation of large-scale biogas, the potential sites are in the city areas with high population density, thus, while calculating the potential commercial and municipal waste availability, only the urban population within the respective districts are taken. Based on the Preliminary Report of National Population Census 2021 and Statistical Information on Nepalese Agriculture 2077/78 (2020/21), 62.28% of the population of each district has been considered to live in the city areas of Sudurpashchim Province.

From Table 4.8, it is seen that Bajura, Dadeldhura and Darchula districts have the least W2E potential and Kanchanpur has the higher potential within the province. The total W2E potential energy is found to be 34,899 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	Paddy	Maize	Wheat	Sugarcane	Buckwheat	Oil seed	Millet	Barley
Kailali	70,520	6,519	34,565	230	24	22,414	356	176
Kanchanpur	48,749	3,378	31,210	5,625	12	8,052	0	8
Dadeldhura	5,961	3,819	9,013	0	35	667	272	174
Baitadi	8,447	11,031	15,901	252	45	329	354	885
Doti	10,715	3,481	12,631	14	13	922	4,625	191
Accham	16,590	6,554	14,453	2	77	615	3,557	444
Darchula	3,494	5,311	5,882	50	96	15	1,263	1,045
Bajhang	6,491	4,185	10,300	0	51	40	2,761	2,391
Bajura	4,251	918	9,831	25	45	306	2,521	973
Total	1,75,218	45,195	1,43,785	6,198	398	33,361	15,709	6,287

(MoALD, 2022 and calculations)

Table 5-10. provides us an estimate of the total agriculture residue produced from different crops and the energy produced from these agricultural residues. The total potential energy produced from such waste is 29.94 million GJ.

Table 5-10. Energy from Agriculture Waste /Year

	Residue in tons								Total residue in tons	Energy produced in Gj
Districts	**Paddy**	**Maize**	**Wheat**	**Sugarcane**	**Buckwheat**	**Oil seed**	**Millet**	**Barley**		
Kailali	4,16,068	35,528	1,16,484	5,529	36	28,690	667	264	6,03,276	9,049,141
Kanchanpur	2,87,619	18,410	1,05,177	1,35,225	18	10,306	0	12	5,56,768	8,351,527
Dadeldhura	35,167	20,813	30,373	0	52	853	516	261	88,041	1,320,619
Baitadi	49,837	60,119	53,586	6,058	67	421	672	1,327	1,72,089	2,581,341
Doti	63,218	18,971	42,566	336	19	1,180	8,787	286	1,35,366	2,030,599
Accham	97,881	35,719	48,706	48	115	787	6,758	666	1,90,682	2,860,230

Darchula	20,614	28,945	19,822	1,202	144	19	2,400	1,567	74,714	1,120,714
Bajhang	38,297	22,808	34,711	0	76	51	5,246	3,586	1,04,776	1,571,643
Bajura	25,081	5,003	33,130	601	67	391	4,790	1,460	70,524	1,057,860
Total	**1,033,786**	**2,46,318**	**4,84,558**	**1,49,000**	**597**	**42,700**	**29,847**	**9,430**	**19,96,238**	**29,943,578**

(MoALD, 2022 and calculations)

5.4 Petroleum Products

Petroleum reserves are being explored under the Department of Mines and Geology, GoN, but proven reserve of feasible petroleum products is yet to be found out in Nepal. The only company that deals with import and sales of petroleum products – that include diesel, petrol, kerosene, and LPG, and others is Nepal Oil Corporation (NOC). The furnace oils and other oil residues are imported by the industries themselves. Thus, the supply of petroleum products is obtained from the regional offices of NOC. District-wise sales data for 2077-78 is shown in **Table 5-11**. All the units for MS, Diesel, and SKO are in kilo liters except for LPG in metric tons (MT). These sales data represent the sales to depots in each district, therefore, if there is no depot in a district, the sales data are not present. It is to be noted that neither the sales from these depots are bound within the district only nor the supply in each district is bound by the capacity of depots only – there are inter-boundary trade and transportation of petroleum fuels. Hence, the supply of petroleum products and their consumption may not tally properly. The sales data from the NOC depot shows that less than of 1% total national sales of diesel, gasoline and kerosene are consumed in Sudurpashchim Province due to limited economic activities in the western part of Nepal, besides individual imports from other provinces.

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

Districts	MS	HSD	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Accham	612	3,495	-	-	-
Baitadi	-	2,762	-	-	-
Dadeldhura	685	3,819	-	-	-
Darchula	150	2,100	-	-	-
Doti	528	3,466	-	-	-
Kailali	15,846	55,786	679	1,656	13,198
Kanchanpur	8,280	23,752	24	-	-
Total	**26,101**	**95,180**	**703**	**1,656**	**13,198**

(Source: NOC 2022)

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

5.5 Electricity

5.5.1 Hydropower Potential

Nepal's theoretical hydropower potential has been estimated at about 83,000 MW and has its technically and economically feasible potential of about 45,000 MW and 42,000 MW respectively (Shrestha, 1966). A study by Bajracharya (2015) shows the total theoretical estimation at annual mean flow to be 103,341 MW. The recent study carried out by WECS in 2019 for the estimation of hydropower potential shows the gross hydropower potential of 72,544 MW from three river basins: Koshi, Gandaki, and Karnali basin which covers 94% of the total gross potential of the country (WECS, 2019). Gross hydropower potential distributions in provinces based on the major three river basins are shown in **Table 5-12.** Koshi Province, which includes most of the Koshi basin incorporates the highest hydropower potential (22,619 MW)- which is 31.2% of the total hydropower potential. Madhesh Province incorporates the lowest hydropower potential (275 MW)-which is 0.4% of 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)

5.5.2 Electricity Supply

Nepal Electricity Authority is the sole organization responsible for the operation and distribution of electricity supply in the country. The total installed capacity of NEA is 627.03 MW (20 hydro and 2 thermal) out of total 2,189.91 MW in Integrated Nepal Power System (INPS). NEA has developed hydropower plants and has projects under proposed plan totaling 240 MW in the Sudurpashchim Province. The annual energy generation from NEA power plants under Generation Directorate is 3,242.483 GWh, which is about 29.29% of the total energy generation in Nepal (NEA Hydropower Stations, Subsidiary Companies and IPPs) (NEA 2022). **Table 5-13** shows the hydropower plants developed, under construction and planned under the IPPs.

Table 5-13. IPPs Developed, Under Construction and Planned Hydropower Plants in Sudurpashchim Province

	In operation	Under construction	Planned Projects

	Installed capacity MW	Installed capacity MW	capacity
Sudurpashchim	145.37	91.05	354.05

(DoED, 2023)

The district-wise electricity supply status as obtained from Nepal Electricity Authority for Sudurpashchim Province is shown in **Table 5-14** along with its use in economic sectors. It shows Kailali and Kanchanpur 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 (55%), followed by the commercial sector with 32%. The agriculture sector consumed 2% of grid electricity and the transport sector consumed nominal grid electricity in the province.

Table 5-14. Electricity Sales in 2077-78 in Sudurpashchim Province

	Agriculture	Commercial	Industry	Residential	Transport	In TJ
Achham	-	3.39	1.55	8.70	-	13.64
Baitadi	0.04	3.86	1.81	11.54	-	17.25
Bajhang	-	1.80	0.55	4.86	-	7.22
Bajura	-	-	-	-	-	-
Dadeldhura	1.99	25.53	6.39	32.43	-	66.34
Darchula	0.31	13.13	4.11	26.24	-	43.79
Doti	0.14	6.62	3.09	18.11	-	27.95
Kailali	4.20	201.12	76.11	264.89	-	546.33
Kanchanpur	10.14	73.68	28.49	195.52	0.10	307.95
Total	**16.82**	**329.14**	**122.12**	**562.29**	**0.10**	**1,030.48**

(NEA, 2022)

5.6 Modern Renewable Energy Sources- Solar &Other Renewables

Alternative Energy Promotion Centre (AEPC) has been promoting renewable energy technologies in Nepal with the objective to raise the living standard of the rural people and protect the environment. As of 2021, it has been able to implement 1,851 nos. of mini and micro hydro projects generating 34.47 MW of electricity among which, 226 nos. of projects are implemented in Sudurpashchim Province generating 6.29 MW of electricity benefitting 68,185 nos. of rural households. The beneficiary household numbers however vary largely at the district level within the province itself based on the feasibility of the technology. Bajura, Bajhang, and Achham have comparatively more beneficiary household covering 28.4%, 24.9%, and 20% household respectively of the total province beneficiary while Kailali (0.3%) and Kanchanpur were least benefitted (**Table 5-15)**. Specific to Sudurpashchim Province, AEPC has been able to install 1864 nos. of improved water mills which are16.3% of the total installations, 139,669 nos. of solar home system units which is 17.5% of the total installations, 619 nos. of institutional solar PV System generating 908.5 kWp power, 91 solar irrigation systems, and 21 solar water pumping systems.

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 9% of the installation has been done in Sudurpashchim Province, i.e, 51,179 Nos. of domestic biogas plants, 87,326 mud ICS and 4,606 metallic ICS.

Table 5-15. Modern Renewable Energy Technologies Installed in Sudurpashchim Province

Technologies	Micro Hydro Projects			Improved Water Mill	Solar Home System	Institutional Solar Photovoltaic System	
District	**No. Projects**	**kW**	**HHs**	**Numbers**	**Numbers**	**Numbers**	**Wp**
Achham	52	1,235.5	13,619	142	24,294	146	1,91,850
Baitadi	30	617.2	6,395	522	23,053	80	1,27,850
Bajhang	58	1,546	17,001	215	22,115	153	2,32,420
Bajura	41	1,758.5	19,391	124	8,414	69	1,03,440
Dadeldhura	12	123	1,173	231	4,606	6	9,500
Darchula	17	553.5	6,266	242	16,495	72	98,055
Doti	14	445	4,154	263	12,953	53	69,920
Kailali	2	9	186	125	25,591	29	53,500
Kanchanpur	0	0	0	0	2,148	11	22,000
Grand Total	**226**	**6,287.7**	**68,185**	**1,864**	**1,39,669**	**619**	**9,08,535**

Technologies	Solar Irrigation System	Solar Water Pumping System	Domestic Biogas	Large Biogas Plant	Improved cook stoves	
District	**Numbers**	**Numbers**	**Numbers**	**Numbers**	**Mud ICS**	**Metalic ICS**
Achham	2	7	28		9,112	204
Baitadi	1	3	78		12,136	19
Bajhang	0	1	283		5,883	642
Bajura	0	0	8		3,247	1,486
Dadeldhura	0	3	216		8,413	15
Darchula	0	3	521		2,505	513
Doti	0	2	131		15,663	134
Kailali	58	2	30,672	2	21,690	756
Kanchanpur	30	0	19,242		8,677	837
Grand Total	**91**	**21**	**51,179**	**2**	**87,326**	**4,606**

(AEPC, 2021)

5.7 Household Energy Production

Traditional energy, particularly agri-residue and animal waste are produced at household level. Fuelwood energy supply is generally mixed from production from own garden as well as bought from the nearest market. The household energy production obtained from the survey shows that in Sudurpashchim Province there is sufficient supply of agri-residue and animal waste to meet its demand for household purposes. However, in the case of fuelwood, approximately 50% is met by own production and remaining demand of fuelwood is supplied from the market. Similarly, for the modern energy supply, biogas and solar are two prominent sources. The biogas plants of various sizes are installed in different districts supplying enough biogas energy which is predominantly used for cooking proposes in residential sector. Regarding solar energy, the small and institutional solar home system installed at household level also supplied adequate energy which is particularly used for lighting purposes at household level (**Table 5-16**). Details of household energy production of each district are given in annex.

Table 5-16. Household Energy Production

(in TJ)

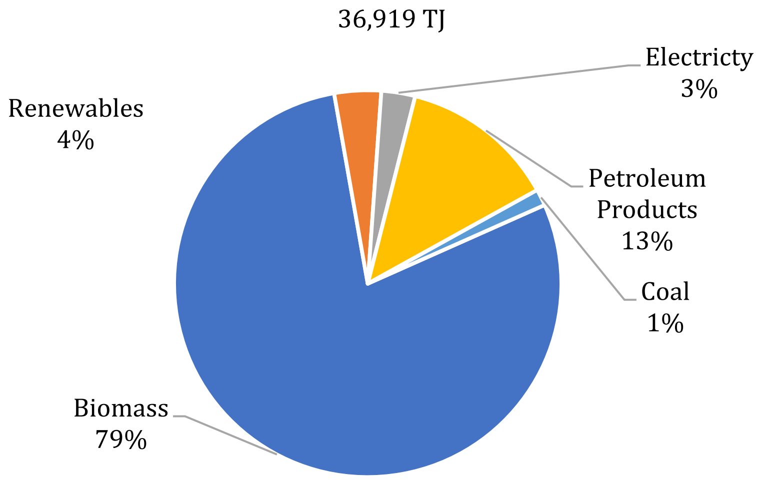
Fuel sources	**TJ**
Fuelwood	12,648.23
Agri residue	1,239.69
Animal waste	11.16
Biogas	1,421.97
Solar PV	0.02

(Calculated from survey data)

6 Energy Consumption in 2021/2022

The total final energy consumption (FEC) in Sudurpashchim Province was found to be 36,919 TJ. Among the six sectors, the residential sector is the highest energy-consuming sector followed by industries. The highest share of energy consumed is still the biomass used particularly in the residential sector for cooking. The abundance of indigenous resources mainly fuelwood in the remote areas as well as the availability of agri-residues provide a comparatively high share of biomass with 79% of total consumption in the province. In addition to that, access to roads and infrastructure has set back the use of more commercial energy forms. It clearly shows the need for energy efficient technologies along with a shift to modern energy resources in the province. As per the NPHC 2021, access to electricity in Sudurpashchim Province is 81% through grid and 16% off-grid (especially solar PV systems). In this province, 70% of households still cook on solid biomass, 17% of households cook on LPG and just 0.3% of households cook on electricity (NSO, 2023).

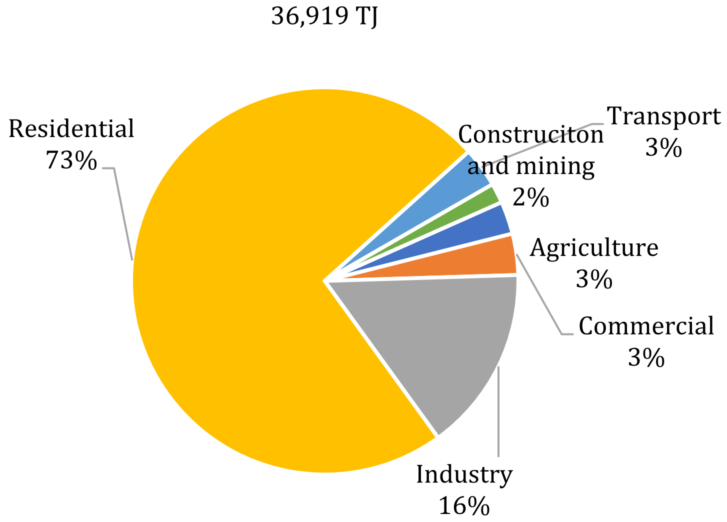
In Sudurpashchim Province, the use of fuelwood is still the major resource among biomass used mainly for cooking and water heating purposes in the residential sector (**Figure 6-1**). The use of agricultural residue is seen to be significant in the industrial sector for thermal purposes. The use of biogas has reduced considerably although it is increasing in number, as the actual use is very little. This can be majorly attributed to the growing consumption of LPG, decreasing livestock farming, people's reluctance to operate residential biogas plants, and due to lower production in colder regions. In addition to that, the use of biogas is limited to mostly residential. The consumption of petroleum products is also increasing as some industries use diesel for electricity generation. The share of renewables and electricity is also comparable to that of national shares.



(Survey, 2022)

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

Figure 6-2 also indicates the change in the consumption pattern in different economic sectors. With the residential being the highest energy-consuming sector at 73% of the total energy consumption, the use of biomass is prevalent in the energy mix. The industrial sector is second at 16% followed by the commercial and transport sector at 3% each. Since there are limited economic development activities, most of the energy is consumed in non-productive activities. Although mechanization in the agricultural sector is gaining popularity, the use of fuel in this sector is very low at 3%. 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 the agricultural sector.



(Survey, 2022)

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

The energy mix by fuel in different sectors can be seen in **Figure 6-2.** Unlike in other provinces in central and eastern Nepal, the major portion of the traditional biomass particularly fuelwood is consumed in the residential sector. Meanwhile, the use of biomass is also prominent in industries for thermal purposes – mainly due to cheaper prices and local/regional availability. The residential sector used the highest share of electricity as well. However, the use of electricity in the commercial sector is also significant but lower than the residential sector. Meanwhile, petrol and diesel are used largely in transport for vehicles, with a considerable share of diesel consumption in the industry sector – for motive power as well as thermal purposes and in the agriculture sector- for water pumping and farm machinery. In addition to that, the industry also uses diesel for electricity generation using diesel generators due to the low reliability of electricity supply. The heavy equipment in the construction and mining sector also seems to demand a considerable amount of petroleum products in this province.

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

in TJ

	Renewables							**Non-renewable**							**Total**
	Conventional renewable					**New Renewables**									
	Traditional biomass			**Modern biomass**											
	Fuelwood	**Agricultural Residue**	**Animal dung**	**Biogas**	**Bio briquettes**	**Solar**	**Grid Electricity**	**Petrol**	**Diesel**	**Kerosene**	**Furnace Oil**	**Aviation turbine fuel**	**LPG**	**Coal**	
Agriculture	-	-	-	-	-	0.35	18.37	17.18	977.57	-	-	-	-	-	**1,013.47**
Commercial	378.90	44.19	4.01	-	-	388.19	344.19	-	-	-	-	-	113.62	1.87	**1,274.97**
Industry	730.81	3,026.49	-	-	-	-	121.08	186.77	1,144.48	13.86	-	-	1.58	506.70	**5,731.77**
Residential	23,884.80	1,044.79	8.93	1,035.43	0.07	17.62	549.84	-	-	8.43		-	508.91	0.07	**27,058.89**
Transport	-	-	-	-	-	-	1.07	579.17	564.45	-	-	89.51	-	-	**1,234.20**
Construction and mining	-	-	-	-	-	-	7.99	127.15	413.53	25.49	-	-	-	-	-
Total	**24,994.51**	**4,115.47**	**12.94**	**1,035.43**	**0.07**	**406.17**	**1,042.54**	**910.28**	**3,100.03**	**47.78**	**-**	**89.51**	**655.30**	**508.64**	**36,918.67**

(Survey, 2022)

Figure 6-3 provides a comprehensive overview of the energy flow in the Sudurpashchim Province. Notably, the primary sources of energy in 2022 are primarily solid biomass and petroleum products, with the residential sector dominating energy consumption. Due to the region's comparatively lower economic activity compared to eastern provinces, the utilization of commercial fuel in industrial and commercial sectors is minimal. Additionally, the use of agricultural machinery is also limited in this context. The figure underscores the unique energy dynamics influenced by both economic factors and regional characteristics within the Sudurpashchim Province.

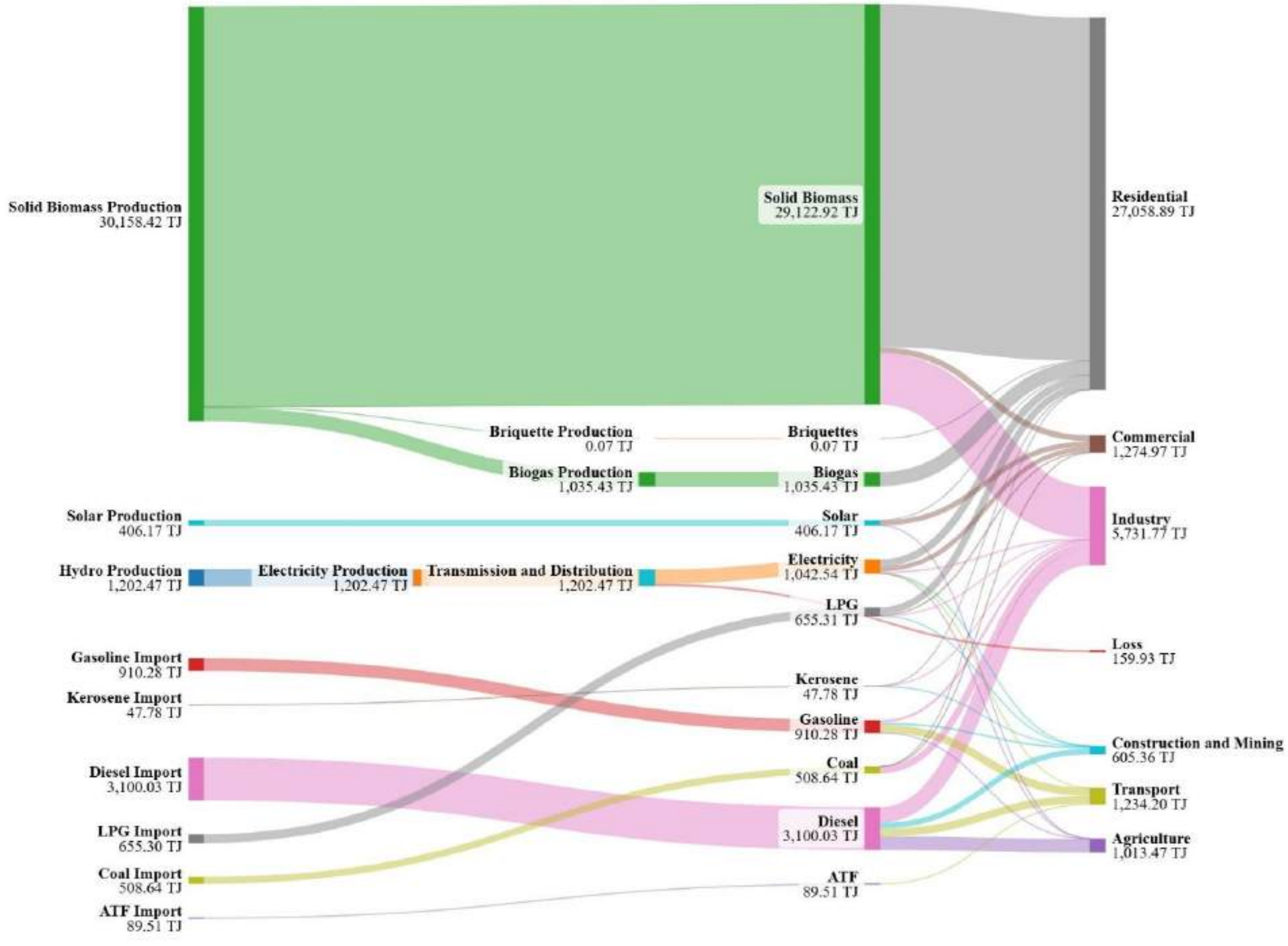


Figure 6-3. Energy Flow in Sudurpashchim Province (Sankey Diagram) in 2022

Table 6-2 shows the energy consumption indicators which highlight the status of energy consumption in Sudurpashchim Province. The total final energy consumption per capita of 13.7 GJ is lower than the national average, yet higher than the more economically active and urbanized provinces. This is due to the usage of inefficient technologies on the one hand and the high amount of energy consumed in the residential sector as there are limited economic activities on the other. The electricity demand per capita also comes far less than the national average as the grid electricity is mostly used for lighting purposes due to poor household connections along with the lower economic status to shift to new technologies as well as unreliable supply systems. The residential electricity consumption per household lies in tier 2 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	13.7
Energy per GVA	GJ per million NRs	125
Share of modern and new renewable energy		6.7%
Electricity Consumption (Total)	kWh per capita	149
Electricity Consumption (Residential)	kWh per HH	265

(Survey, 2022)

6.1 Energy Consumption in Sudurpashchim Province by Ecological Regions

The ecological distribution of energy consumption is affected by population, as well as energy access. As seen in **Table 6-3.** The mountain region has the least amount of energy consumed – primarily due to the least number of people in the region. The Terai and hilly regions consumed a large share of energy at 46% and 31% respectively, as these regions have most of the population and had good access to other services. Most of the economic activities are concentrated in Terai region due to accessibility and availability of resources. In terms of energy types as well, the use of traditional biomass is dominant in the mountain and hilly regions. Meanwhile, commercial fuels such as petroleum products and electricity are highly used in terai as well as in hilly regions. Sector-wise, energy consumption is yet again influenced by population and economic activity. Hence, the energy consumption share is high in terai and hilly regions with combined consumption of 60% in residential sector.

Table 6-3. Energy Consumptions by Ecological Regions and Sectors

In TJ

		Fuelwood	Agricultural residue	Animal waste	Coal	Kerosene	LPG	Diesel	Gasoline	ATF	Furnace oil	Electricity	Biogas	briquettes	Solar thermal	Solar PV	Total
Mountain		**6,178.42**	**27.75**	**10.07**	**0.17**	**-**	**42.06**	**70.95**	**1.51**	**-**	**-**	**28.75**	**9.31**	**-**	**-**	**212.41**	**6,581.40**
	Agriculture	-	-	-	-	-	-	16.70	1.51	-	-	0.52	-	-		-	18.72
	Commercial	175.37	27.75	1.14	0.17	-	18.01	-	-	-	-	8.82	-	-	-	206.48	437.74
	Industrial	1.09	-		-	-	0.08	54.25	-	-	-	2.02	-	-			57.45
	Residential	6,001.96	-	8.93	-	-	23.97	-	-	-	-	17.39	-	-	-	5.93	6,067.49
Hills		**10,095.43**	**717.27**	**2.87**	**1.76**	**6.87**	**192.67**	**86.31**	**-**	**-**	**-**	**159.68**	**1.38**	**0.05**	**0.01**	**182.45**	**11,446.75**
	Agriculture							25.25	-	-	-	3.26				-	28.51
	Commercial	160.79	16.44	2.87	1.70	-	34.39	-	-	-	-	57.65	-	-	0.00	174.26	448.10
	Industrial	29.43	0.13		-	-	0.32	61.06	-	-	-	15.73					106.67
	Residential	9,905.21	700.70	-	0.07	6.87	157.96	-	-	-	-	83.05	1.38	0.05	0.01	8.19	10,863.48
Terai		**8,720.66**	**3,370.45**	**-**	**506.70**	**15.42**	**389.37**	**1,964.79**	**202.45**	**-**	**-**	**845.05**	**1,024.74**	**0.02**	**-**	**11.30**	**17,050.96**
	Agriculture	-	-	-	-	-	-	935.62	15.67	-	-	14.60				0.35	966.25
	Commercial	42.75	-	-	-	-	61.22	-	-	-	-	277.72	-	-	-	7.45	389.13
	Industrial	700.29	3,026.36		506.70	13.86	1.17	1,029.17	186.77	-	-	103.33					5,567.66
	Residential	7,977.63	344.09	-	-	1.56	326.98	-	-	-	-	449.40	1,024.74	0.02	-	3.50	10,127.92
Province																	
	Transport	-	-	-	-	-	-	564.45	579.17	89.51		1.07	-	-	-	-	1,234.20
	Construction and mining	-	-	-	-	25.49	31.20	413.53	127.15		-	7.99	-	-	-	-	605.36
Grand total		**24,994.51**	**4,115.47**	**12.94**	**508.64**	**47.78**	**655.30**	**3,100.03**	**910.28**	**89.51**	**-**	**1,042.54**	**1,035.43**	**0.07**	**0.01**	**406.16**	**36,918.67**

(Survey, 2022)

6.2 Agriculture Sector

The agriculture sector in Sudurpashchim Province consumed about 1,013 TJ and among this, the use of diesel for water pumping and farm machinery is very high in comparison to the consumption of petrol and electricity **(Figure 6-4)** Although the penetration of solar pumping systems for irrigation is gaining popularity, its use has been limited. It is mainly due to the geographical difficulty in hilly and mountainous regions.

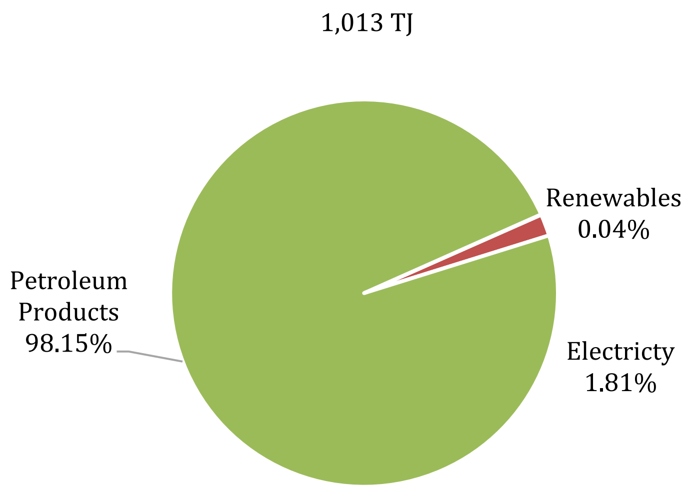


Figure 6-4. Energy Mix in Agriculture Sector

Table 6-4 shows that most of the diesel is used for farm machinery. A large portion of irrigation in Sudurpashchim 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

	Water pumping	Tilling	Threshing	In TJ
Petrol	15.67	-	1.51	**17.18**
Diesel	155.17	523.79	298.61	**977.57**
Electricity	18.37	0.00	0.00	**18.37**
Solar	0.35	-	-	**0.35**
Total	**189.56**	**523.79**	**300.12**	**1,013.47**

(Survey, 2022)

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

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

In TJ

	Petrol	Diesel	Electricity	Solar	Total
Mountain	**1.51**	**16.70**	**0.52**	**-**	**18.72**
Bajhang	1.51	11.19	0.02	-	12.71
Bajura	-	1.96	0.50	-	2.45
Darchula	-	3.55	-	-	3.55
Hills	**-**	**25.25**	**3.26**	**-**	**28.51**
Achham	-	8.87	0.64	-	9.51
Baitadi	-	1.74	-	-	1.74
Dadeldhura	-	4.81	2.36	-	7.17
Doti	-	9.83	0.25	-	10.08
Terai	**15.67**	**935.62**	**14.60**	**0.35**	**966.25**
Kailali	15.67	449.14	4.04	0.32	469.18
Kanchanpur	-	486.48	10.55	0.03	497.07
Total	**17.18**	**977.57**	**18.37**	**0.35**	**1,013.47**

(Survey, 2022)

6.3 Commercial Sector

The commercial sector consumed comparatively less energy in this province at 3% with 1,275 TJ. The energy mix shows the nearly homogenous mixture of all energy forms in this sector. The renewables and electricity share are comparable to biomass as they are used primarily in hotels, restaurants, schools, offices, barracks, and community centers for cooking and electrical appliances **Figure 6-5.** The historical case of lower access of energy before inundated the region with the RETs, while with increasing economic activity in accessible regions, the use of commercial energy has also increased. The electricity is used for electrical appliances and lighting as well as space heating, space cooling, and water boiling. LPG is mostly used for cooking but is also used for water boiling and space heating and a small portion is used for social events as well.

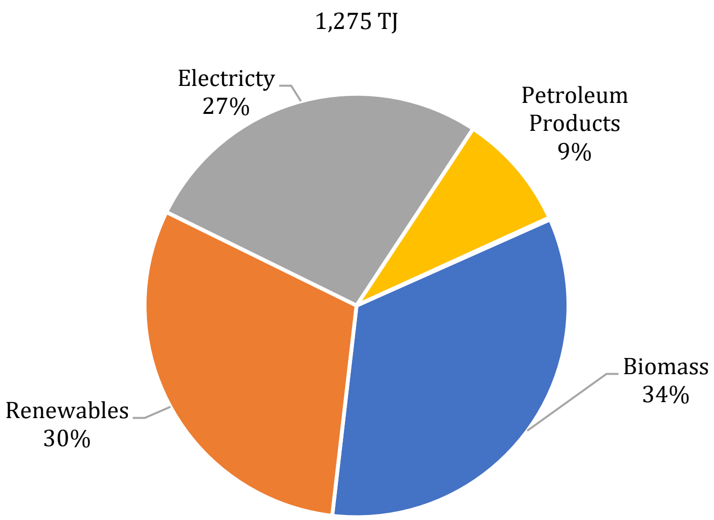


Figure 6-5. Energy Mix in Commercial Sector

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

Table 6-6. Energy Consumption in Commercial Sector

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	Other use	Total
Wood	378.13	0.78	-	-	-	-	-	-	**378.90**
Agri residue	44.19	-	-	-	-	-	-	-	**44.19**
Animal waste	4.01	-	-	-	-	-	-	-	**4.01**
Coal	1.87	-	-	-	-	-	-	-	**1.87**
LPG	93.87	12.36	6.79	-	-	-	0.61	-	**113.62**
Electricity	28.25	2.72	0.05	9.57	19.62	283.99	-	-	**344.19**
Solar thermal	-	0.00	-	-	-	-	-	-	**0.00**
Solar PV	-	-	-	-	38.91	349.29	-	-	**388.19**
Total	**550.31**	**15.85**	**6.83**	**9.57**	**58.52**	**633.28**	**0.61**	**-**	**1,274.97**

(Survey, 2022)

Subsector-wise, the largest amount of energy is seen to be used in the social sector which comprises of hospitals, schools, and offices. It uses solar PV as the major source for lighting and electrical appliances. The use of clean energy surpasses the commercial sector in this province, not because of the high penetration of RETs, but due to lower commercial activities that demand high energy usage. On the other hand, accommodation and food services use considerable amounts of energy in the form of electricity, LPG and biomass. **(Table 6-7).** The financial and real estate sector uses the least amount of energy as their primary demand is for lighting and other electrical equipment.

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

In TJ

	Trade and Retail	Accommodation	Financial	Social	Others	Total
Wood	106.27	119.90	0.22	137.66	14.86	**378.90**
Agricultural residue	17.43	18.35	-	8.41	-	**44.19**
Animal waste	3.32	0.69	-	-	-	**4.01**
Coal	1.13	0.74	-	-	-	**1.87**
LPG	20.55	78.25	0.40	5.39	9.03	**113.62**
Electricity	18.59	193.76	6.51	53.98	71.34	**344.19**
Solar thermal	-	0.00	-	-	-	**0.00**
Solar PV	0.01	0.00	0.00	388.15	0.03	**388.19**
	167.29	**411.69**	**7.13**	**593.60**	**95.26**	**1,274.97**

(Survey, 2022)

As for energy-using activities in sub-sectors, the highest amount of energy is used for cooking, second highest is electrical appliances, followed by biomass as seen in **Table 6-6 and Table 6-7**. Trade and Retail, and Accommodation sub-sector uses the highest energy in the form of cooking. The consumption of energy is comparatively high in subsectors Social and Others via electrical appliances. **(Table 6-8)**

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	143.11	6.76	0.00	2.43	8.96	6.04	-	-	**167.29**
Accommodation	237.29	8.40	0.01	2.24	4.84	158.32	0.61	-	**411.69**
Financial	0.66	-	0.01	0.06	1.28	5.12	-	-	**7.13**
Social	152.00	0.67	0.00	3.30	41.11	396.52	-	-	**593.60**
Others	17.26	0.02	6.81	1.54	2.34	67.28	-	-	**95.26**
	550.31	**15.85**	**6.83**	**9.57**	**58.52**	**633.28**	**0.61**	**-**	**1,274.97**

(Survey, 2022)

Ecologically, energy consumption in the commercial sector is nearly similar. The energy use in hilly and mountain regions is mainly for tourists, where cooking is the main energy consumer. In Terai there are service-oriented institutions that use more electricity **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	214.37	1.66	6.62	0.52	23.37	191.21	-	**437.74**
Hills	205.75	11.77	0.21	0.41	23.77	205.59	0.61	**448.10**
Terai	130.19	2.42	0.01	8.64	11.39	236.48		**389.13**
	550.31	**15.85**	**6.83**	**9.57**	**58.52**	**633.28**	**0.61**	**1,274.97**

(Survey, 2022)

Fuel-wise also, energy consumption is almost similarly distributed in the ecological regions (**Table 6-10).** However, cooking fuel-wise, it is evident that more traditional sources of energy are used in the mountains and hilly regions. Meanwhile, consumption of commercial fuels like electricity and LPG is higher in the more accessible Terai region. The usage of solar PV is higher in mountains and hilly regions.

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

In TJ

	Wood	Agricultural residue	Animal waste	Coal	Kerosene	LPG	Electricity	Solar thermal	Solar PV	Total
Mountain	175.37	27.75	1.14	0.17	-	18.01	8.82	-	206.48	**437.74**
Hills	160.79	16.44	2.87	1.70	-	34.39	57.65	0.00	174.26	**448.10**
Terai	42.75	-	-	-	-	61.22	277.72	-	7.45	**389.13**
Total	**378.90**	**44.19**	**4.01**	**1.87**	**-**	**113.62**	**344.19**	**0.00**	**388.19**	**1,274.97**

(Survey, 2022)

6.4 Residential Sector

The residential sector is the highest energy-consuming sector in the Sudurpashchim Province, and its consumption is 27,059TJ. In the energy mix, the use of biomass is dominant in this province followed by renewables **(Figure 6-6)**. The use of electricity is increasing as the grid connection is expanding throughout the country. A large share of renewables comes from Solar PV used mainly for lighting purposes.

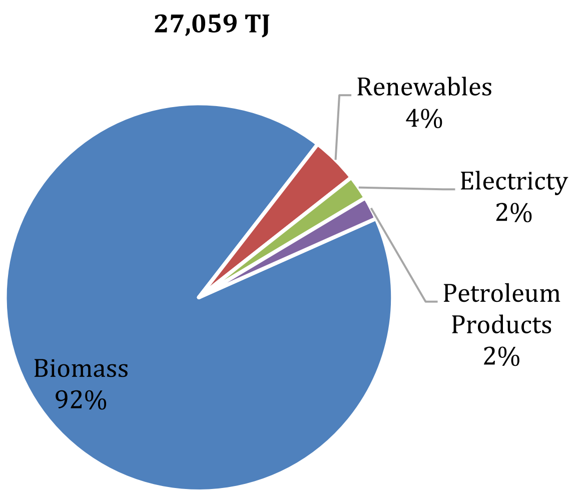


Figure 6-6. Energy Mix in Residential Sector

Table 6-11 gives the energy mix for various end-use activities in the residential sector. It can be observed that cooking consumes 93% of total residential energy with biomass as the primary source. LPG and Biogas are also used for cooking purposes. A significant amount of electricity is seen to be used for electrical appliances with limited use for cooking purposes which is due mainly to poor connection as well as low per capita income and reluctance to shift to new technologies. The current use of traditional biomass and LPG shows significant efforts required for the energy transition to e-cooking.

Table 6-11. Energy Consumptions in Residential Sector

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Wood	22,716.67	1,150.60	-	-	-	-	17.52	**23,884.80**
Agricultural residue	993.35	51.44	-	-	-	-	-	**1,044.79**
Animal waste	8.93	-	-	-	-	-	-	**8.93**
Coal	0.07	-	-	-	-	-	-	**0.07**
Kerosene	-	-	-	-	-	-	8.43	**8.43**
LPG	504.18	4.50	-	-	-	-	0.24	**508.91**
Electricity	13.81	-	0.00	21.46	72.98	441.59	-	**549.84**
Biogas	1,035.43	-	-	-	-	-	-	**1,035.43**
Briquettes	-	0.04	0.01	-	-	-	0.02	**0.07**
Solar thermal	-	0.01	-	-	-	-	-	**0.01**
Solar PV	-	-	-	-	17.62	-	-	**17.62**
Total	**25,272.44**	**1,206.58**	**0.01**	**21.46**	**90.60**	**441.59**	**26.22**	**27,058.89**

(Survey, 2022)

The population is lower in rural municipalities, and so is the amount of energy consumed (**Table 6-12 and Table 6-13**). However, the energy intensity, i.e., per capita energy is higher in rural areas. This is mainly due to the use of inefficient technologies in rural areas. 96% of energy is used in the form of traditional biomass for cooking in rural areas. The use of electrical appliances is lower in comparison to urban areas. The use of solar PV is comparable to grid electricity for lighting in rural areas indicating the dissemination of renewable energy technology to most parts of the province through various government and non-governmental projects.

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

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	11,878.43	699.83	-	-	-	-	4.78	**12,583.03**
Agricultural residue	213.83	-	-	-	-	-	-	**213.83**
Kerosene	-	-	-	-	-	-	6.80	**6.80**
LPG	154.88	1.54	-	-	-	-	-	**156.41**
Electricity	2.07	-	-	1.18	16.26	78.92	-	**98.42**
Biogas	404.31	-	-	-	-	-	-	**404.31**
Solar PV	-	-	-	-	14.09	-	-	**14.09**
Total	**12,653.51**	**701.36**	**-**	**1.18**	**30.35**	**78.92**	**11.57**	**13,476.89**

(Survey, 2022)

The urban area is also dependent upon biomass even though the consumption of LPG and electricity is also significant. The use of solar PV in urban areas is however lower compared to the rural areas due to the access to grid electricity. Cooking is the major energy-consuming end-use activity with biomass as the dominant form of energy. Grid electricity is the only source for electrical appliances whereas solar PV is used for lighting electrical appliances as well as lighting.

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

in TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Fuelwood	10,838.25	450.77	-	-	-	-	12.75	**11,301.77**
Agricultural residue	779.52	51.44	-	-	-	-	-	**830.96**
Animal waste	8.93	-	-	-	-	-	-	**8.93**
Coal	0.07	-	-	-	-	-	-	**0.07**
Kerosene	-	-	-	-	-	-	1.64	**1.64**
LPG	349.30	2.96	-	-	-	-	0.24	**352.50**
Electricity	11.74	-	0.00	20.28	56.72	362.67	-	**451.41**
Biogas	631.12	-	-	-	-	-	-	**631.12**
Briquettes	-	0.04	0.01	-	-	-	0.02	**0.07**
Solar thermal	-	0.01	-	-	-	-	-	**0.01**
Solar PV	-	-	-	-	3.52	-	-	**3.52**
Total	**12,618.93**	**505.22**	**0.01**	**20.28**	**60.25**	**362.67**	**14.65**	**13,582.00**

(Survey, 2022)

The ecological distribution of energy consumption in the residential sector is highly influenced by the population distribution as seen in **Table 6-14 and Table 6-15**. Particularly, the hilly and terai regions use significant amounts of energy mostly for cooking purposes.

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

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Other uses	In TJ
Mountain	6,012.96	20.08	-	0.14	13.85	9.29	11.17	**6,067.49**
Hills	9,589.18	1,180.76	0.01	0.66	21.73	62.46	8.68	**10,863.48**
Terai	9,670.31	5.73	-	20.66	55.02	369.84	6.36	**10,127.92**
Total	**16,492.84**	**10.46**	**4.66**	**3.77**	**49.27**	**93.38**	**112.90**	**27,058.89**

(Survey, 2022)

In terms of energy type, it is observed that hilly and terai regions are predominantly using biomass as well as other forms of energy. Meanwhile, the use of commercial energy is progressively decreasing with higher ecological regions. Meanwhile, the usage of biogas is very good in the Terai region, particularly due to climatic suitability as well as accessibility and population size. In general, a large amount of energy is seen to be used in the Kailali, Kanchanpur of the Terai region, and Achham and Baitadi of hilly region.

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

	Fuelwood	Agri-residue	Animal waste	Coal	Kerosene	LPG	Electricity	biogas	Briquettes	Solar Thermal	Solar PV	In TJ
Mountain	6,001.96	-	8.93	-	-	23.97	17.39	9.31	-	-	5.93	**6,067.49**
Hills	9,905.21	700.70	-	0.07	6.87	157.96	83.05	1.38	0.05	0.01	8.19	**10,863.48**
Terai	7,977.63	344.09	-	-	1.56	326.98	449.40	1,024.74	0.02	-	3.50	**10,127.92**
	16,332.00	**21.65**		**0.08**	**0.78**	**241.83**	**140.78**	**3.33**	**0.23**	**0.01**	**26.62**	**27,058.89**

(Survey, 2022)

6.5 Industrial Sector

The industrial sector consumed 5,731 TJ of energy in Sudurpashchim Province which is approximately 16% of the total provincial energy. The energy mix in the industrial sector is shown in **Figure 6-7.** Biomass still contributes 66% of industrial energy used mainly in food and beverage industries in the form of agri-residue. Petroleum products, mainly diesel, is another major source of fuels used for thermal purposes as well as generators for electricity and motive power. Coal is also used for thermal processes in boilers as well as furnaces. With the gradual shift to clean energy, electricity usage has increased to some extent in industries reaching its share of 2%.

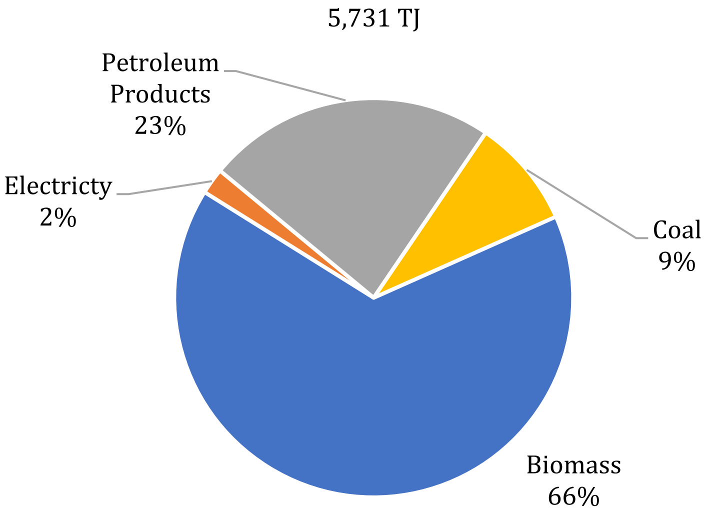


Figure 6-7. Energy Mix in Industrial Sector

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, coal, and diesel are the major sources. In this province as well, the use of furnace oil seems to be insignificant. Diesel is used for motive power as well as for other uses, particularly for electricity generation. The electricity consumption comes mainly from the shift to electric motor equipment.

Table 6-16. Energy Consumption in Industry Sector

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total in TJ
Fuelwood	-	57.13	673.68	-	-	**730.81**
Agri residue	-	1,835.32	701.80	-	489.38	**3,026.49**
Coal	-	95.70	411.00	-	-	**506.70**
kerosene	-	13.86	-	-	-	**13.86**
LPG	-	0.07	1.37	-	0.14	**1.58**
Diesel	-	-	281.85	751.01	111.62	**1,144.48**
Gasoline	-	-	-	186.77	-	**186.77**
Furnace oil	-	-	-	-	-	**-**
Electricity	4.52	-	3.79	100.60	12.18	**121.08**
Total	**4.52**	**2,002.07**	**2,073.49**	**1,038.38**	**613.32**	**5,731.77**

(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, bricks and structural clay products, and textile and leather industries consumed comparatively higher energy consuming 50%, 46%, and 2% respectively. They consumed diesel, coal, 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	Kerosene	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Food Beverage and Tobacco	82.67	2,407.49	-	13.86	1.36	302.84	-	-	71.69	**2,879.90**
Textile and Leather Goods	-	-	-	-	-	114.12	-	-	13.88	**128.00**
Chemical Rubber and Plastic	-	-	-	-	-	-	-	-	3.03	**3.03**
Mechanical Engineering and Manufacturing	-	-	-	-	0.08	-	-	-	9.84	**9.92**
Electrical Engineering Products	-	-	-	-	-	-	-	-	-	**-**
Wood Products and Paper	-	-	-	-	-	54.25	-	-	8.38	**62.64**
Bricks & Structural Clay Products	641.60	618.87	506.70	-	-	671.36	186.77	-	4.13	**2,629.44**
Cement & Nonmetallic Products	6.54	0.13	-	-	-	-	-	-	8.09	**14.76**
Other Manufacturing	-	-	-	-	0.14	1.91	-	-	2.03	**4.08**
Total	**730.81**	**3,026.49**	**506.70**	**13.86**	**1.58**	**1,144.48**	**186.77**	**-**	**121.08**	**5,731.77**

(Survey 2022)

Table 6-18 shows energy consumption in the industrial subsectors by its end-use services. It shows that most of the fuel is used for thermal heating from boiler and process heat with 35% and 36% each respectively mostly in food and beverage industries and bricks and structural clay products. Approximately 18% of energy is used for motive power followed by 11% for other uses which are particularly for electricity production through the diesel generators.

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

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Food Beverage and Tobacco	2.25	1,891.79	898.45	74.83	12.57	**2,879.90**
Textile and Leather Goods	0.05	-	-	127.95	0.00	**128.00**
Chemical Rubber and Plastic	0.00	-	-	3.03	-	**3.03**
Mechanical Engineering and Manufacturing	0.02	-	0.85	6.50	2.56	**9.92**
Electrical Engineering Products	-	-	-	-	-	**-**
Wood Products and Paper	0.06	-	-	5.18	57.39	**62.64**
Bricks & Structural Clay Products	1.55	103.61	1,174.18	812.14	537.96	**2,629.44**
Cement and Non-metallic Products	0.46	6.67	-	7.63	-	**14.76**
Other Manufacturing	0.12	-	-	1.12	2.83	**4.08**
Total	**4.52**	**2,002.07**	**2,073.49**	**1,038.38**	**613.32**	**5,731.77**

(Survey 2022)

Table 6-19 shows fuel-wise energy consumption by ecological region in Sudurpashchim Province. Kailali and Kanchanpur districts which lie in the Terai regions together consumed approximately 97% of total industrial energy as most of the energy-intensive industries are established in these areas. Also, most of the economic activities are centered in those two districts due to mainly accessibility and availability of resources. The mountainous region covers three districts namely Bajhang, Bajura, and

Darchula where the industrial activities are minimal, thus consuming approximately 1% of the total consumption. On the other hand, the hilly region consists of four districts and consumed around 2% of the total consumption in the province.

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

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Mountain	0.04	-	2.26	1.14	54.00	**57.45**
Hills	0.49	29.63	60.31	8.03	8.21	**106.67**
Terai	3.99	1,972.45	2,010.91	1,029.21	551.10	**5,567.66**
Total	**4.52**	**2,002.07**	**2,073.49**	**1,038.38**	**613.32**	**5,731.77**

(Survey 2022)

Fuel-wise, traditional biomass, agricultural residue, coal, diesel, gasoline, and electricity are mostly consumed in the Terai region. Diesel, fuelwood, LPG, and electricity are also used in other regions as well but most of the consumption as seen from **Table 6-20 .**is consumed in the Terai regions as many industries are based in this region.

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

	Fuelwood	Agri residue	Coal	Kerosene	LPG	Diesel	Gasoline	Electricity	Total
Mountain	1.09	-	-	-	0.08	54.25	-	2.02	**57.45**
Hills	29.43	0.13	-	-	0.32	61.06	-	15.73	**106.67**
Terai	700.29	3,026.36	506.70	13.86	1.17	1,029.17	186.77	103.33	**5,567.66**
Total	**730.81**	**3,026.49**	**506.70**	**13.86**	**1.58**	**1,144.48**	**186.77**	**1211.08**	**5,731.77**

(Survey 2022)

A huge amount of heat energy is obtained from fossil fuels – primarily from diesel, coal, and gasoline. Diesel is also used for thermal uses in addition to using in motive power. The grid electricity consumption share however is only 2% in Sudurpashchim 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 into cleaner energy even in the industrial sector which was 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. There is enthusiasm and willingness to switch 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 generally 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 full operation currently. However, the two other international airports are not in full operations. 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 Sudurpashchim Province, road transport is emphasized due to its major share in overall transportation. For this purpose, road transport is disaggregated into the following categories **(Table 6-21).**

Table 6-21. Vehicle Categories

Sub-sectors	Devices	End-use
Service Type		
Private Personal	car, jeep, van, motorcycle, bus, minibus, tempo, etc.	Passenger
Private Institutional	car, jeep, van, pickup, etc.	Passenger/Freight
Public Local-Short Distance	Bus, minibus, jeep, van, tempo, etc.	Passenger
Public Long Distance	Bus, minibus, jeep, van, etc..	Passenger
Freight	Truck, minitruck, pick-up, cargo van	Freight
Fuel type		
Diesel	car, jeep, van, bus, 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)
Bajura	692	8,112	79,089
Dhangadhi	2,560	150,295	102,060
Sanphebagar, Achham	63	1,296	
Sudurpashchim Province	**3,315**	**159,703**	**181,149**

(Survey, 2022)

6.6.1 Transport Sector Energy Consumption by Fuel Types

The transport sector consumed 1,234 TJ of energy in 2022 which is nearly 3% of the total energy consumption in the province. The energy mix in the transportation sector is shown in **Figure 6-8.** It shows higher consumption of petrol at 47% of the energy consumed in the transport sector. It is seconded by the consumption of diesel at 46% of the total energy consumption in the transport sector.

Consequently, 18% of total diesel and 63% of total petrol consumed in the province are solely used for transport activities.

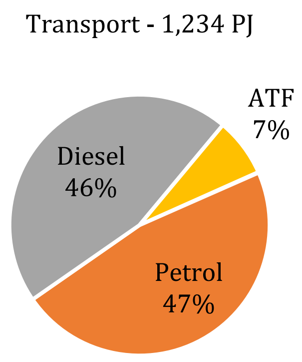


Figure 6-8. Energy Mix in Transport Sector

The energy consumption in transport by subsectors and fuel types is shown in **Table 6-23.** The energy consumption by public passenger vehicles is 14%, that of private passenger vehicles is 48%, freight vehicle is 31%, and the remaining 7% by air transport.

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

Sub-sector		Diesel	Gasoline	ATF	Electric	
Public Passenger	Bus	130.72	-	-	-	130.72
	Microbus	18.06	-	-	-	18.06
	Minibus	7.45	-	-	-	7.45
	Tempo	15.28	-	-	-	15.28
	E rickshaw	-	-	-	1.07	1.07
Total		**171.52**	-	-	**1.07**	**172.59**
Private Passenger	Car	6.54	11.33	-	-	17.87
	Jeep	4.76	9.11	-	-	13.87
	Van	0.67	1.16	-	-	1.83
	Motorcycle		557.57	-	-	557.57
Total		**11.97**	**579.17**	-	-	**591.13**
Freight	Truck	222.44	-	-	-	222.44
	Mini Truck	17.82	-	-	-	17.82
	Tractor	97.49	-	-	-	97.49
	Pickup	41.09	-	-	-	41.09
	Cargo van	2.13	-	-	-	2.13
Total		**380.97**	-	-	-	**380.97**
Aviation		-	-	89.51	-	**89.51**
Grand Total		**564.45**	**579.17**	**89.51**	**1.07**	**1,234.20**[7]

(Survey 2022)

The transport sector is heavily dependent on imported petroleum products, so there is a huge opportunity to switch to electric mobility. The use of e-rickshaws is getting popular, but this trend is not affecting the fuel-efficient passenger carriers such as e-buses. However, the prospect of e-rickshaws substituting fuel-inefficient vehicles – i.e., motorcycles and cars is promising.

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

6.7 Construction and Mining Sector

The construction and mining sector in Sudurpashchim used the least amount of energy among the six sectors at 605 TJ. Among these, the highest amount of energy is used in the form of diesel – mostly for heavy equipment. Diesel is also used for thermal purposes in addition to LPG. LPG is also used by on-site workers for cooking and heating purposes of bitumen for mixing with asphalt. There may be overlapping of energy consumption in the freight transport subsector as dumper trucks are widely used in the construction sector.

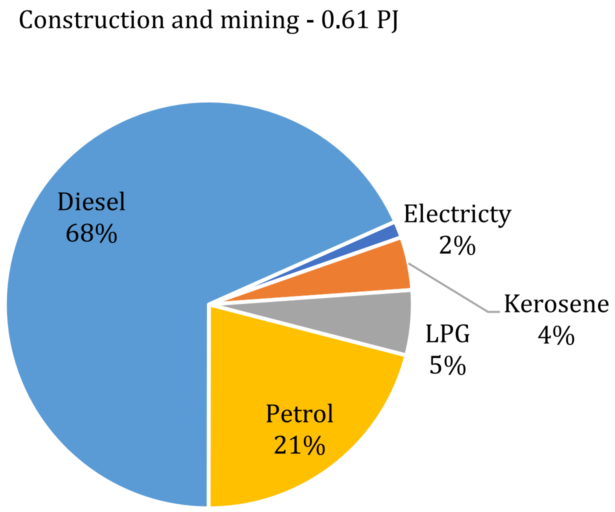


Figure 6-9. Energy Mix in Construction and Mining Sector

6.8 Fuel Demand by Time of Day

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

In the residential sector, it can be seen in **Figure 6-10** that the usage of fuelwood starts as early as 5 AM and peaks between 7 AM to 9 AM. Its usage is low during daytime. However, it again peaks between 7 PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals. The daytime usage is for other purposes such as food processing, animal feed preparation and other life habits.

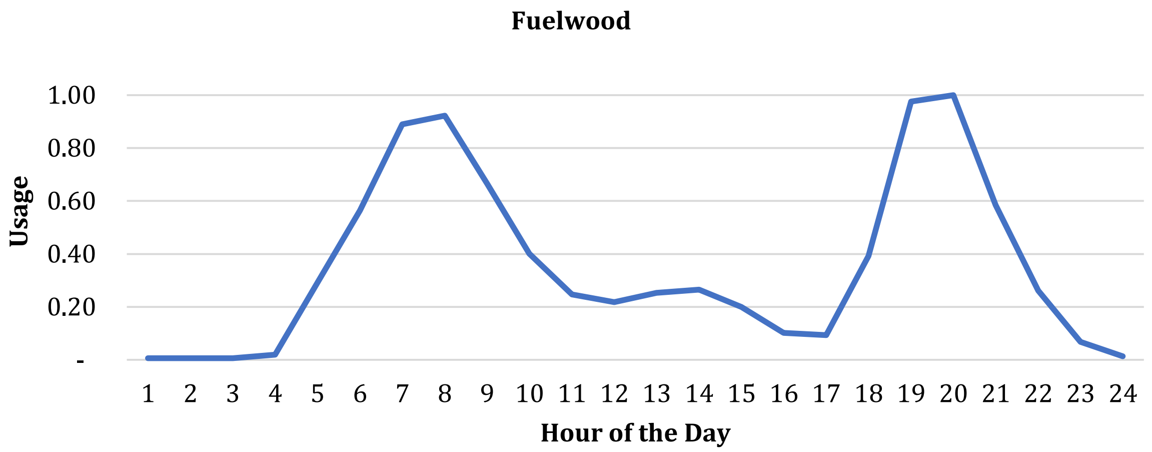


Figure 6-10. Energy usage/load Distribution Curve for Fuelwood in Residential Sector.

It can be seen in Figure 6-11 that the usage of LPG starts as early as 5 AM and peaks between 7 to 9AM. 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 differs than for fuelwood as these being easy to use, they do not take long time to start fire as well as due to lifestyle habits.

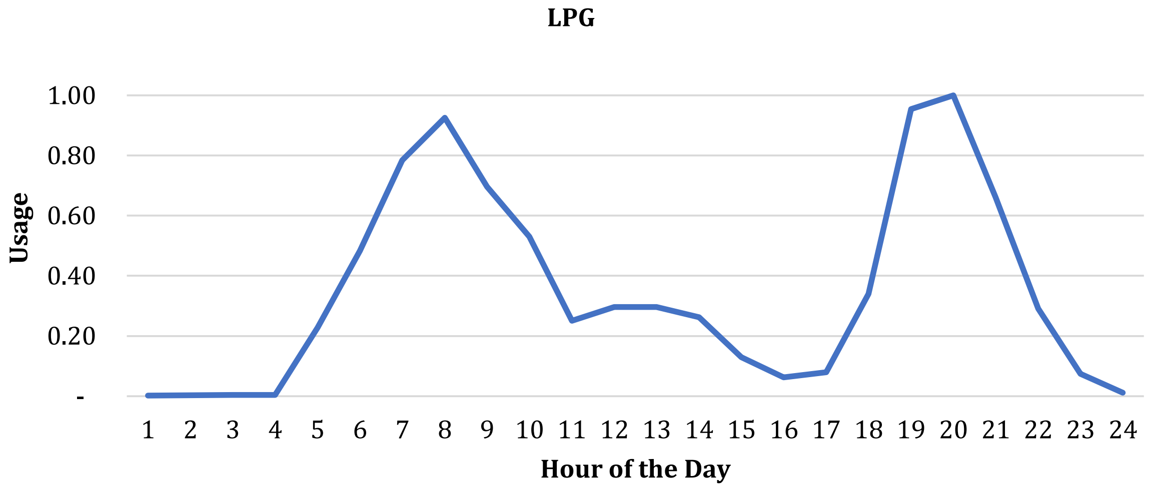


Figure 6-11. Energy usage/load Distribution Curve for LPG in Residential Sector.

It can be seen in Figure 6-12 that the usage of electricity goes up as early as 4 AM and peaks between 5 to 6 AM. Its usage is comparatively lower during daytime. However, it again peaks between 7 PM to 10 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.

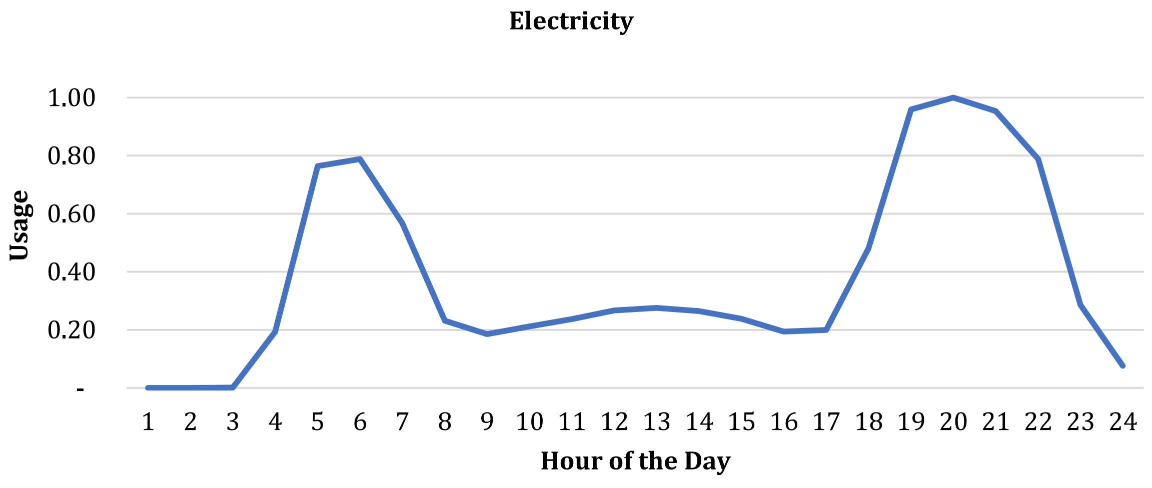


Figure 6-12. Energy Usage/Load Distribution Curve for Electricity in Residential Sector.

The commercial sector has bit different characteristics than the residential sector. In commercial sector, as seen in **Figure 6-13** that the usage of fuelwood starts as early as 5 AM and peaks between 7 to 9 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.

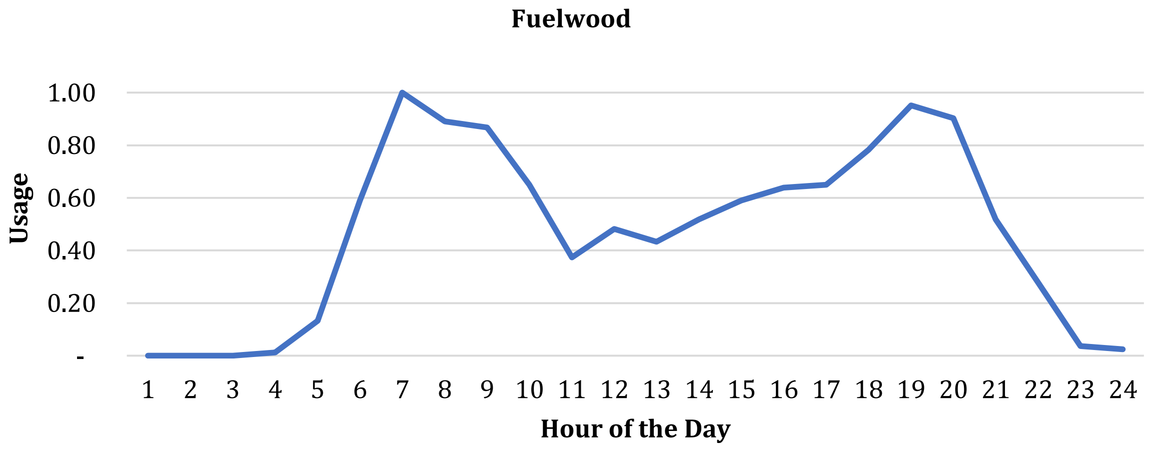


Figure 6-13. Energy Usage/Load Distribution Curve for Fuelwood in Commercial Sector.

It can be seen in **Figure 6-14** that the usage of LPG peaks at two spots of daytime, with little bump in afternoon. The LPG usage starts at 5 AM and first peaks at 7 AM to 9 AM. Its usage stays fairly constant with high usage during daytime. Finally, it again peaks between 7PM 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.

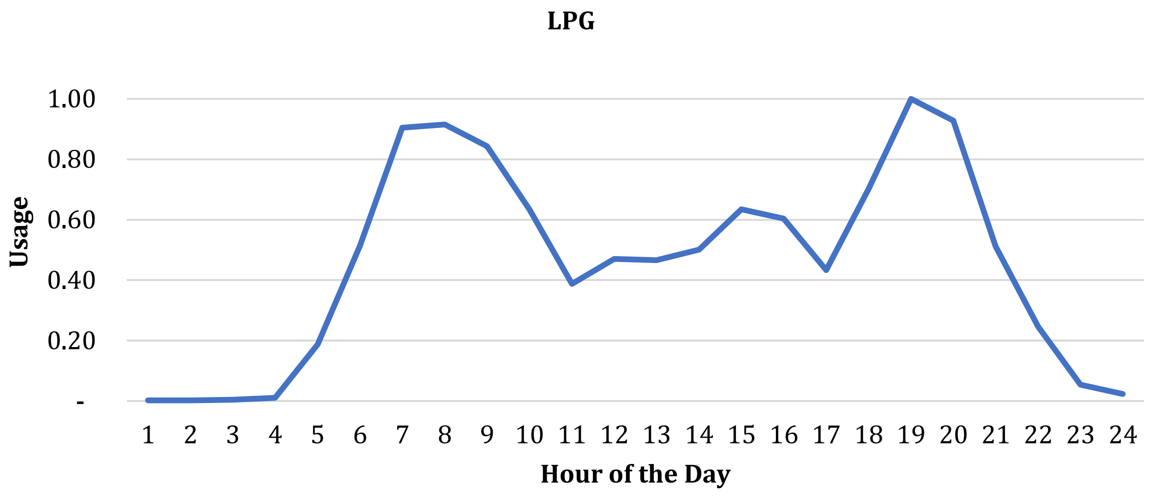


Figure 6-14. Energy Usage/Load Distribution Curve for LPG in Commercial Sector.

The electricity uses in commercial uh sector starts at 5:00 AM, as seen from **Figure 6-15,** when the e service activities slowly start such as in schools or hospitals then it begins to rise up till the middle of the day when the activities are still going on including office activities and other commercial services. The usage remains nearly constant with high usage during the daytime, during office hours. 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 other in commercial sector.

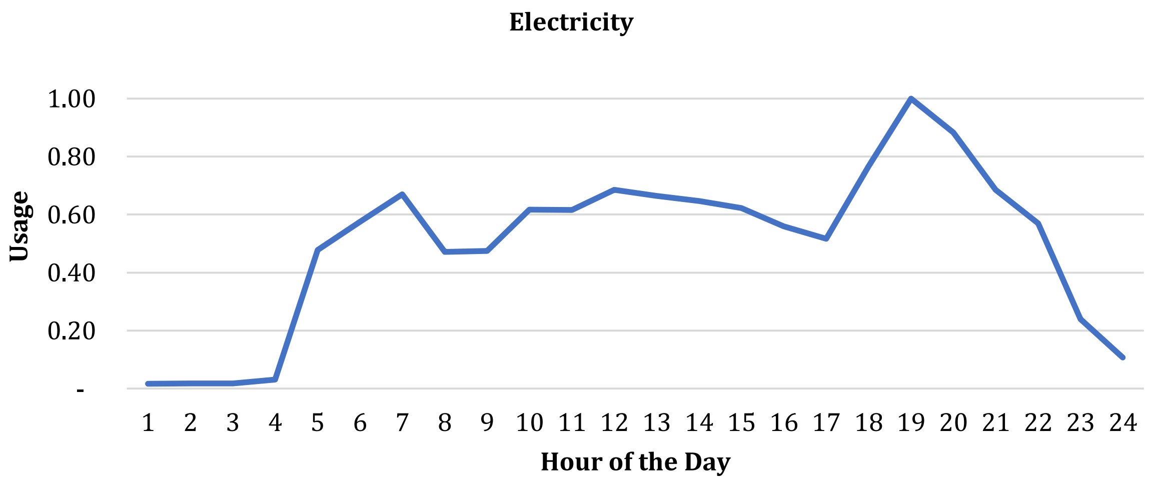
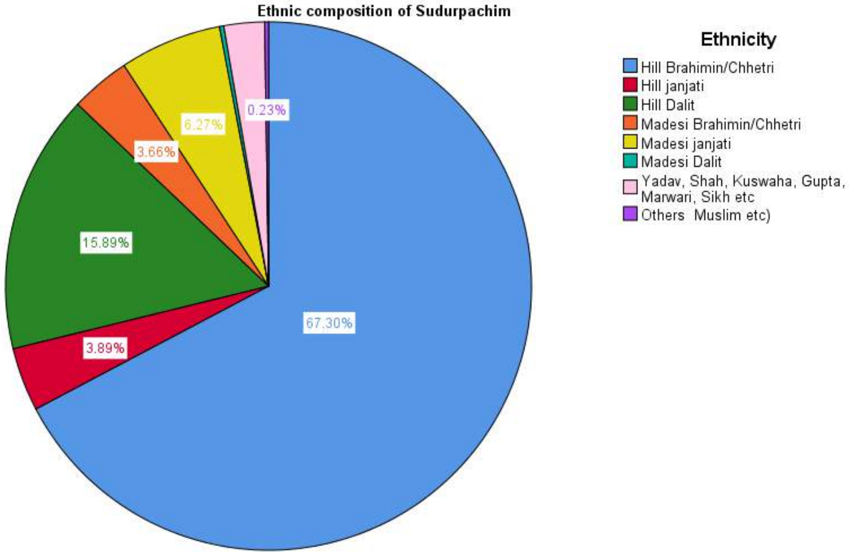


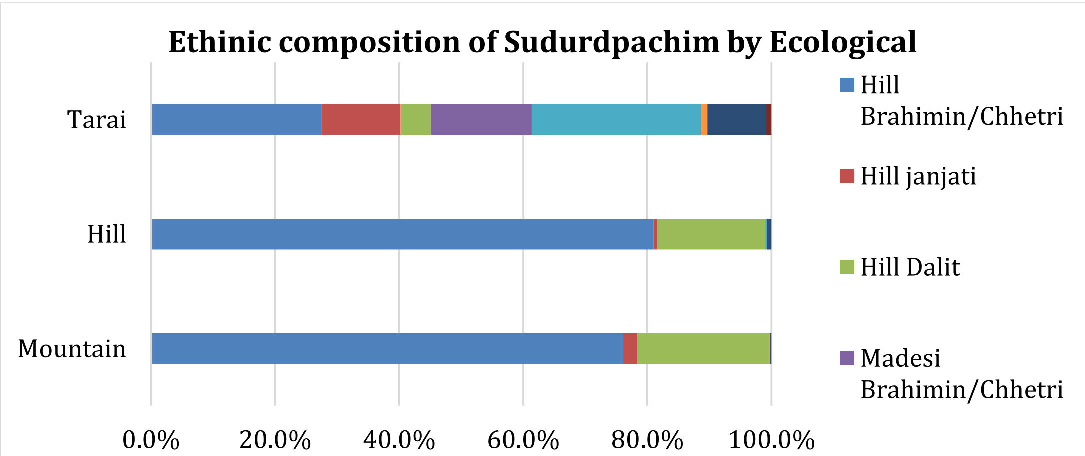
Figure 6-15. Energy Usage/Load Distribution Curve for Electricity in Commercial Sector.

7 Socio-economic and Technical Analysis

7.1 Socio-Economic Status

Sudurpashchim Province ranges from low Terai to the high Mountain Ranges. Overall, Hill Brahmin/Chhetri are dominant followed by Madhesi dalit in Sudurpashchim Province. In mountain and hilly regions, the hill Brahmin/Chhetri are the dominant ethnic groups. Whereas in Terai, the Madhesi janajatis are the dominant ethnic group followed by Hill/Brahmin/Chhetri (**Figure 7-1**).

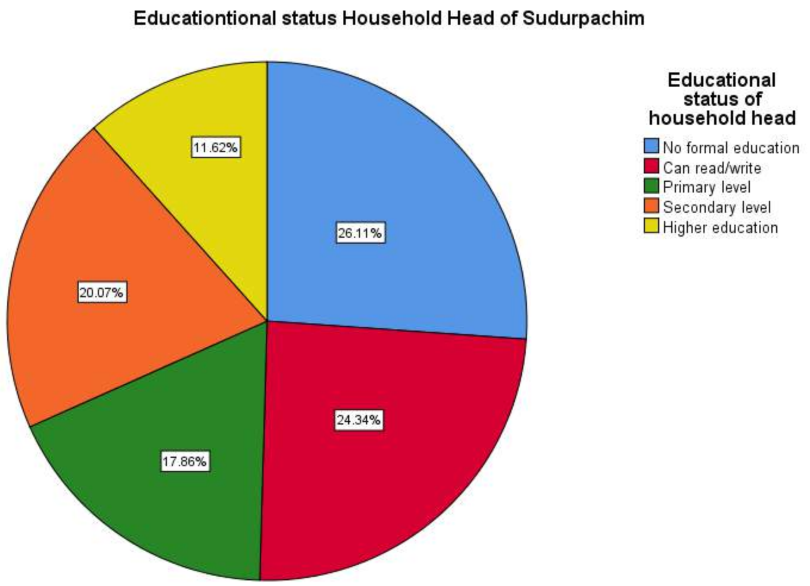


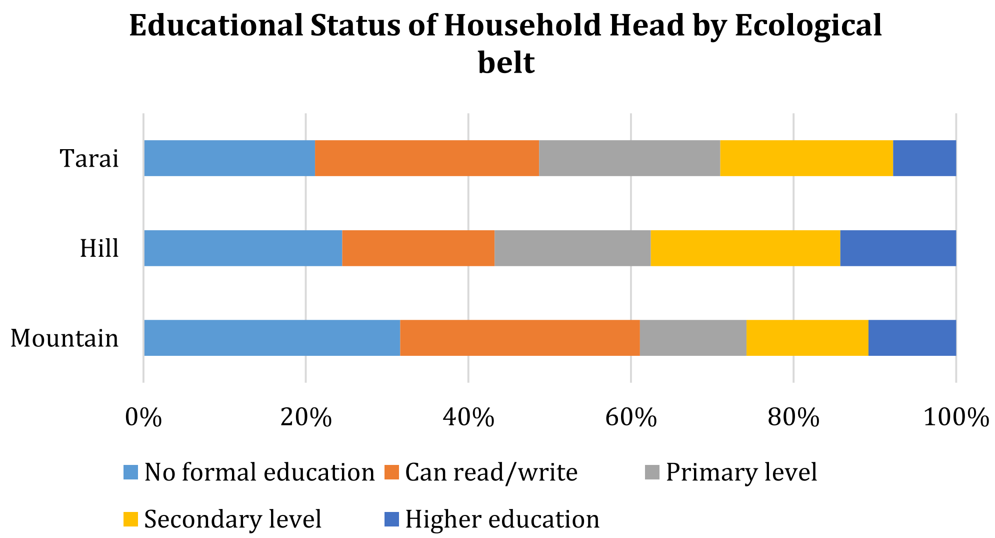


(Survey, 2022)

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

It is evident that education level has an influence on decision-making. Thus, looking at the education level of household heads in this Province, it was seen that substantial household heads have no formal education followed by the partially literate. Nearly 26% of the household heads do not have a formal education **(Figure 7-2)** And the impact can be seen in the energy mix–fuelwood and other biomass still being predominant in the energy mix. Regionally, the Terai region has the highest proportion of the population with no formal education. The education level seems higher in the Hill and Mountain regions comparatively.

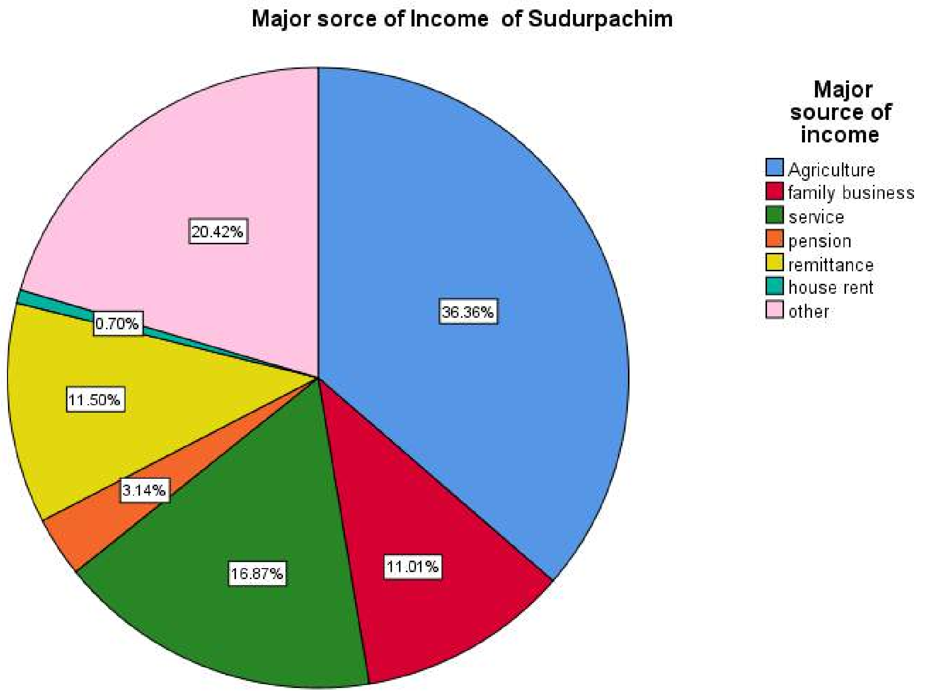


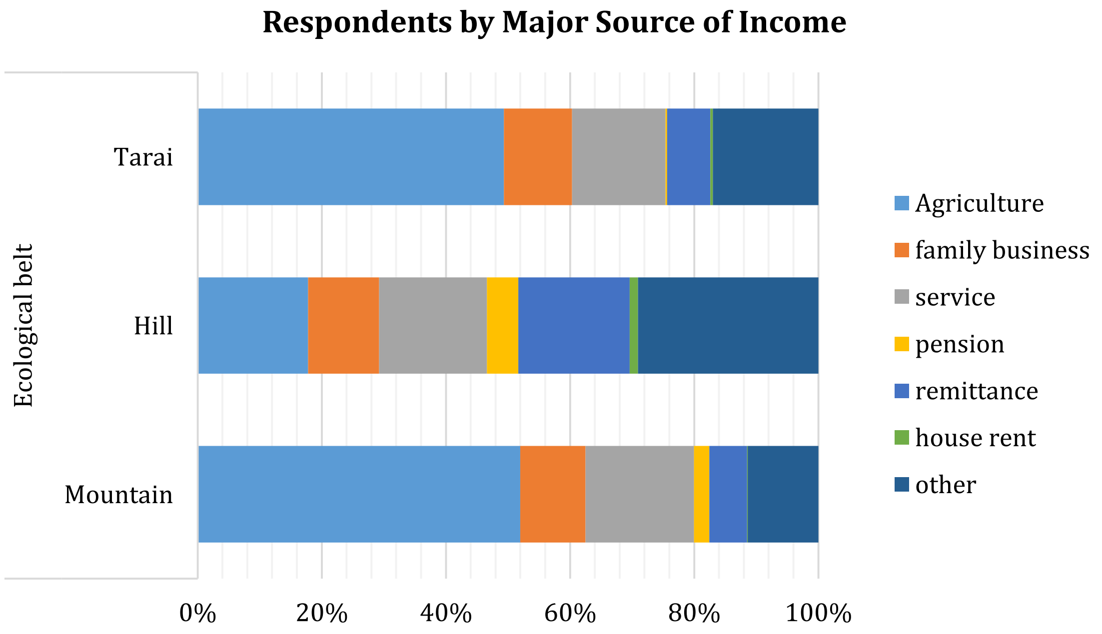


(Survey, 2022)

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

Another important aspect of socioeconomic behavior is the sources and level of income. The major source of income of the respondents is agriculture followed by family business and services. Only a low share of people is independent on income from pension and house rent. The income from remittance and other jobs, including wages, is also substantial. In the Mountain region nearly 36.36% of families have agriculture as their major source of income shown in **Figure 7-3.**





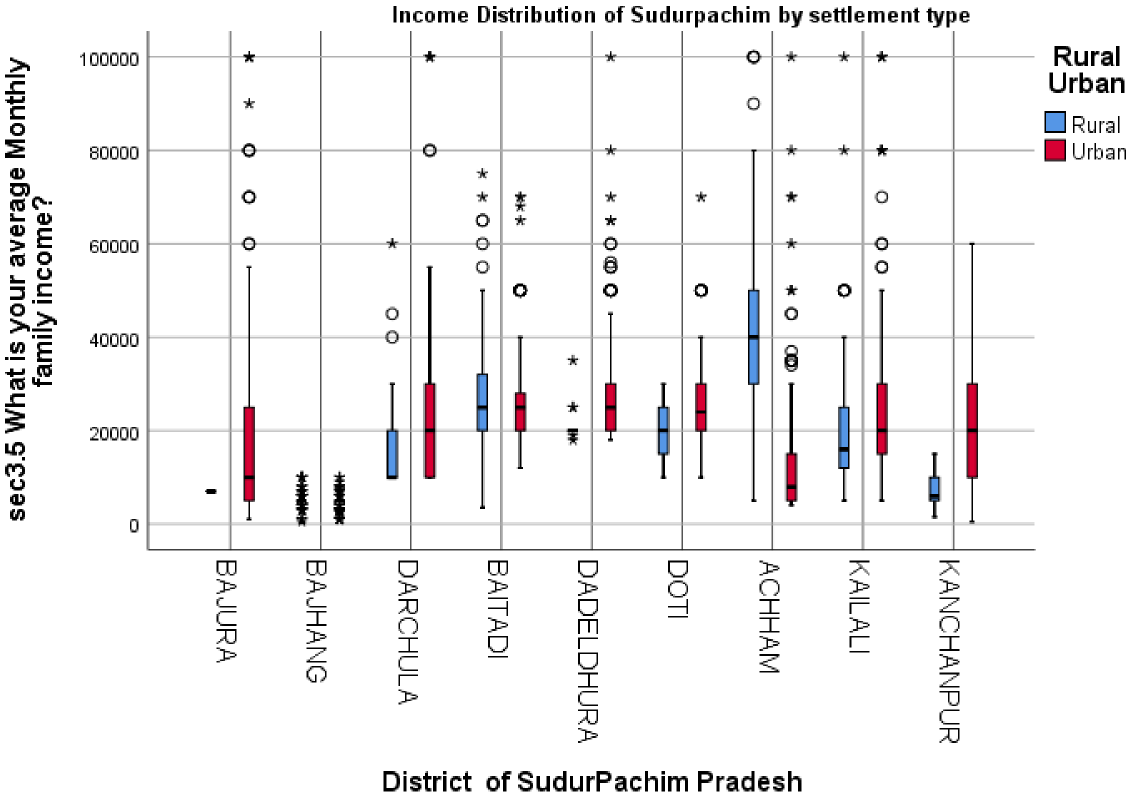
(Survey, 2022)

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

The average monthly family income level ranges from as low as 22,317.00 per month, which comes to an average of NRs 267,804.00 annual income per household in Sudurpashchim Province as per sample survey. This income level is slightly low with reference to the income level as per the National Living Standards survey of Rs 30,121.00 per month[8]. Compared by ecological regions, the income level is higher on average in Terai than the hills, whereas the mountain region has the lowest income level. This is mostly due to higher economic activity in the Terai region due to easy access to economic

[8] Fifth Household Budget Survey Nepal Rastra Bank 2014-2015

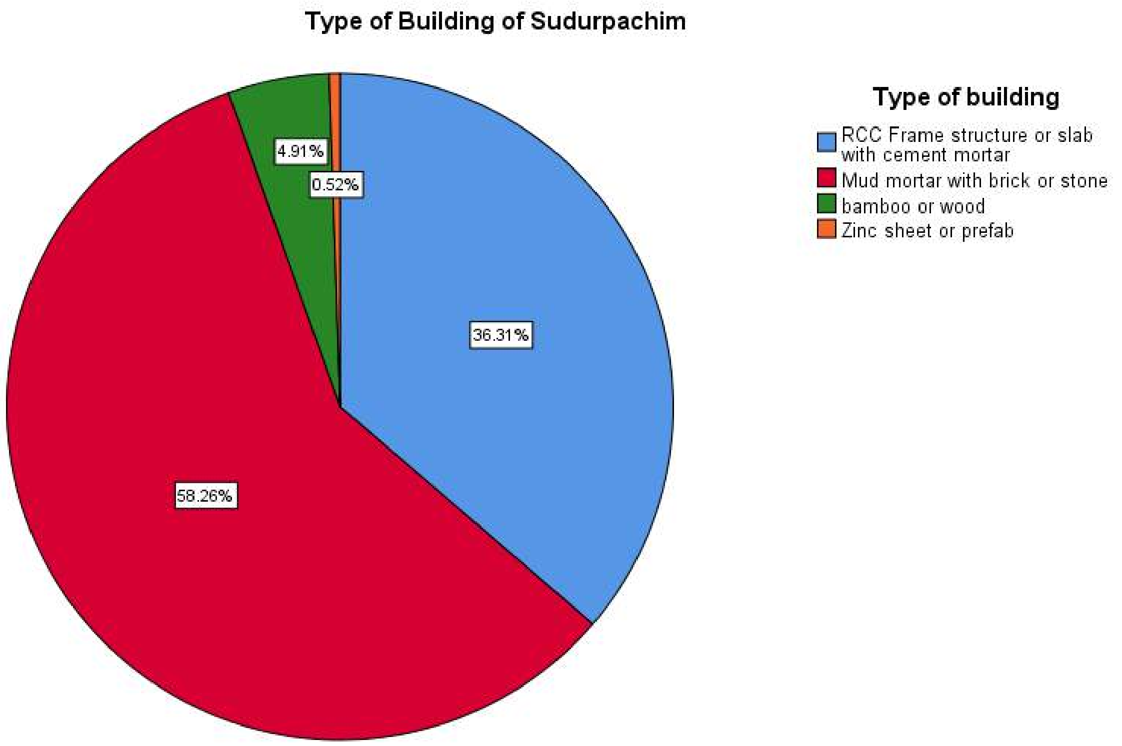
centers – even India as a neighboring country. However, there is a huge variance from mean level of income in most of the cases which is evident from **Figure 7-4.**

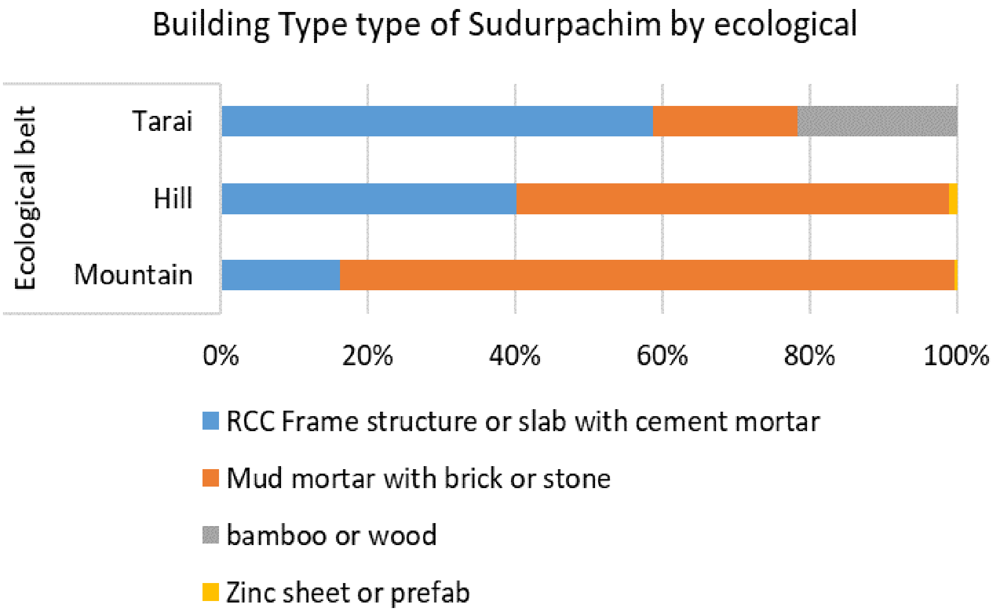


(Survey, 2022)

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

In Sudurpashchim Province, more than 58.26% 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 an increasing trend, especially after the earthquake in 2015.

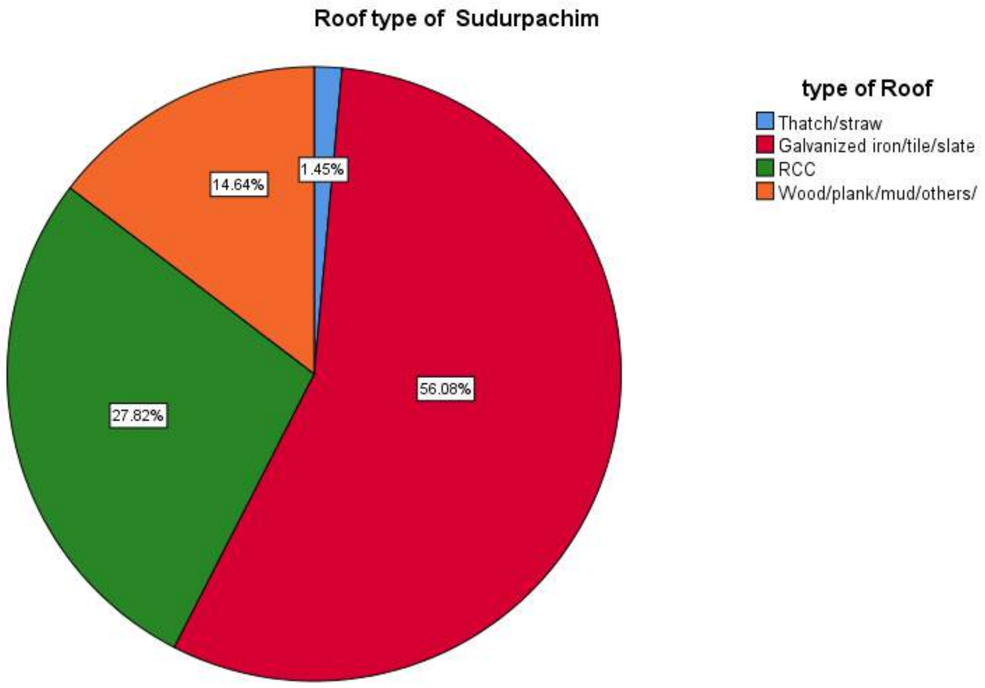


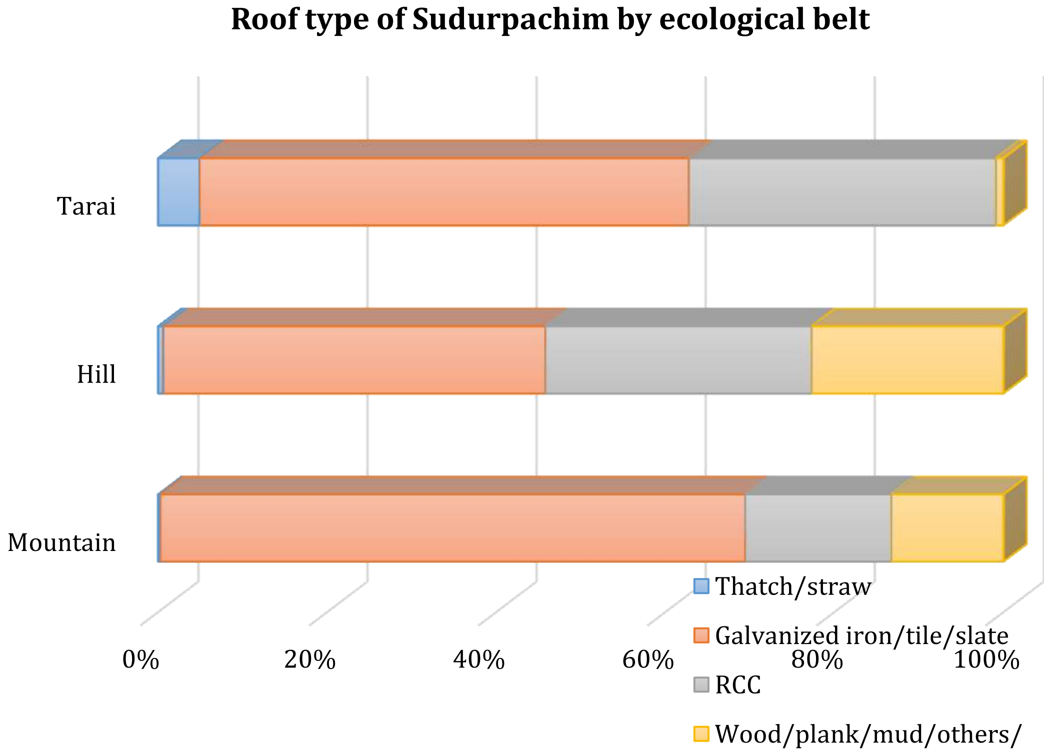


(Survey, 2022)

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

Meanwhile, for the roof structure, the majority of households still used 56% galvanized iron sheet or tile, or slate followed by RCC and then RCC in older houses **(Figure 7-6).**



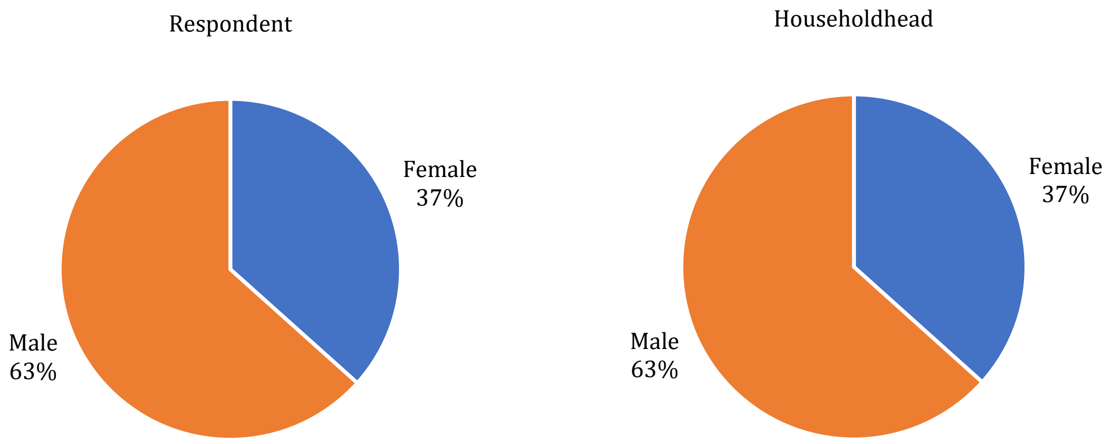


(Survey, 2022)

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

7.2 Respondents by Gender

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



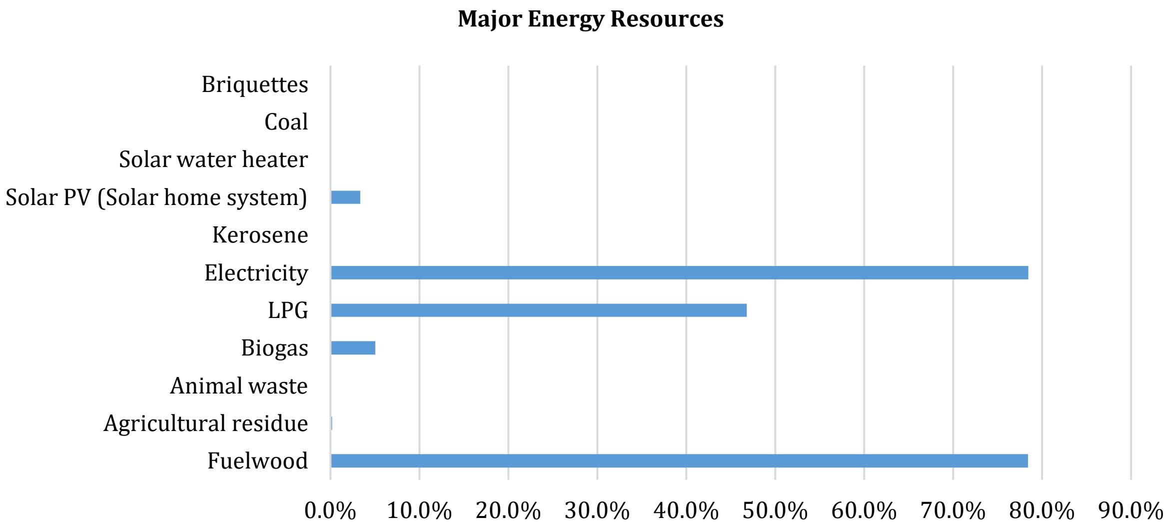
(Survey, 2022)

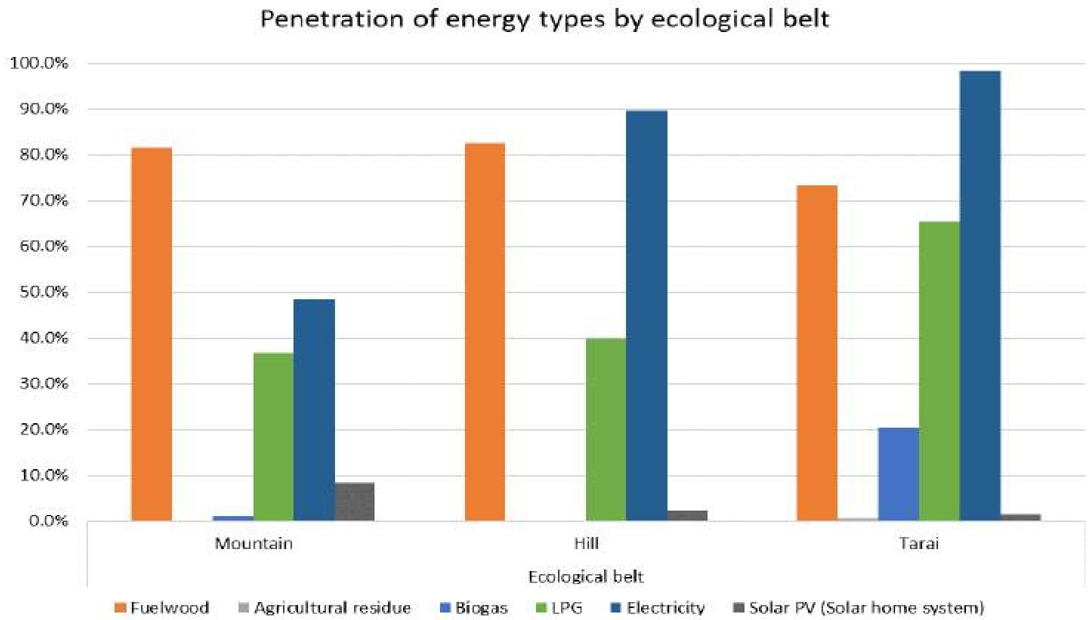
Figure 7-7: Mix of Household Respondents and the Household Head by Gender

7.3 Energy Access

Figure 7-8 shows the penetration of energy types in the Sudurpashchim. Over 89% of the population has access to electricity. Second to that is the use of fuelwood, where nearly 60% of the respondents still use fuelwood as a source of energy followed by LPG. This energy mix shows that the society in Sudurpashchim Province is still at phase of energy transition from traditional to modern fuels. Even though electricity is highly available, the consumption and use of fuelwood and other biomass is still high. This is because –traditional technology is very much energy inefficient requiring higher consumption and most importantly, these energy sources can be attained free of cost if opportunity cost of fuelwood collection is not considered.

Thus, people tend to use these sources more often. **Figure 7-8** highlights fuel stacking in Sudurpashchim, and it is normal practice in developing countries as consumers cannot depend on one source of energy due to affordability, fuel security, and traditional practices. The district-wise penetration of energy sources is given in **Annex VI.**





(Survey, 2022)

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

Table 7-1 shows how many people paid for commercially traded energy sources. At current times, even fuelwood is being traded at an average rate of NRs. 364 per bhari (around 40 kg) on average, with the highest in Terai and the lowest in mountains. Meanwhile the LPG in Koshi Province costs at around NR 1874 per cylinder, with transportation costs. It is seen that LPG is available at marked prices in Terai, however, due to transport cost. LPG cost more in hills and in mountain regions. These account for nearly NRs 1 per MJ of energy for fuelwood, while more than NR 2.5 per MJ of LPG. Thus, the upfront cost of commercial energy still seems high. But if we take energy efficiency into consideration, the cost of useful energy would be much lower for commercial energy.

Table 7-1: Prices of fuels in Sudurpashchim Province

Fuel price by settlement type			
		Rural Urban	
	Sudurpashchim	Rural	Urban
Fuelwood (Rs./bhari)	364	314	381
LPG(Rs./cyl))	1836.8	1857.7	1832.5

(Survey, 2022)

Fuel price by District of Sudurpashchim										
	Unit	Bajura	Bajhang	Darchula	Baitadi	Dadeldhura	Doti	Achham	Kailali	Kanchanpur
		Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Fuelwood	Bhari (40 Kg)		412		377	340	210	375	359	350
LPG	cylinder	1,928.4	2,004.1	1,886.4	1,872.4	1,863.7	1,886.1	2,287.6	1,593.3	1,636.8

(Survey, 2022)

8 Energy Scenario Analysis

8.1 Scenario Development

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

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

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

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

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

Provincial energy demand projections from the Model for Analysis of Energy Demand (MAED) – a freely available software developed at the International Atomic Energy Agency (IAEA) - are input exogenously into the IEEC modelling framework.

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

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

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

- *Sustainable Energy Development (SED) Scenario*

For combined policy analysis, REF scenario is taken as reference for 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 Sudurpashchim Province is expected to grow from current level of 37 PJ in 2022 to 36 PJ in 2030 and 64 PJ in yea 2050 respectively., the energy demand will almost double in three decades, with an average annual growth rate of energy demand is 2% per annum. The little dip in the middle of the period is due to the enhanced penetration of ICS, that reduces fuelwood demand. Meanwhile, per capita energy demand is expected to grow from 14 GJ in 2022 to 21 GJ in 2050 in this scenario which indicates that the energy demand in future is going to increase more than the population growth, primarily in productive 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*	29.12	28.08	26.18	25.85	27.03	29.98	35.59
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	1.04	1.05	1.08	1.11	1.14	1.17	1.20
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.41	0.46	0.60	0.81	1.10	1.53	2.18
			Grid Electricity	1.04	1.25	1.48	1.81	2.28	2.97	3.98
Non-renewable			Petrol	0.91	0.75	0.82	0.91	1.04	1.21	1.47
			Diesel	3.10	3.35	4.37	5.83	7.94	11.05	15.69
			Kerosene	0.05	0.03	0.04	0.05	0.07	0.10	0.14
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.09	0.09	0.09	0.10	0.10	0.10	0.10
			LPG	0.66	0.68	0.74	0.83	0.95	1.12	1.36
			Coal	0.51	0.57	0.75	1.01	1.39	1.94	2.53
Total				36.92	36.31	36.16	38.31	43.03	51.16	64.24

(Calculations, 2022)

Figure 8-1 depicts the growth primary solid biomass (fuelwood, agri- residue and animal dung) will remain high in in future years even though the use of petroleum products will increase at much higher rate of 5% per annum. Wherein electricity demand would grow at 4.9% per annum, yet its demand in the total share will still be low. The demand for electricity would reach four-fold in 2050.

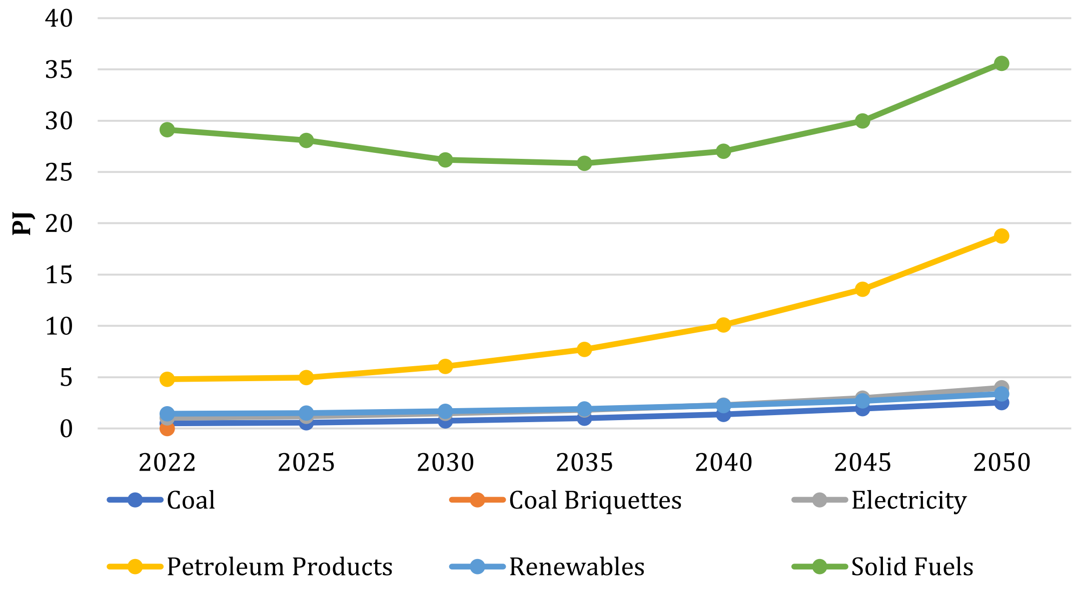
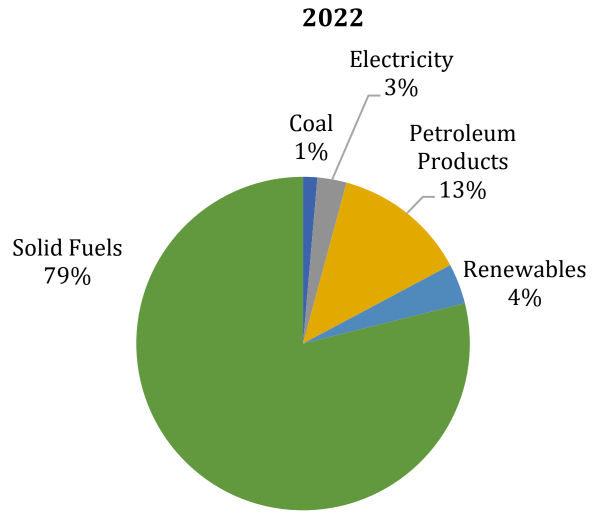
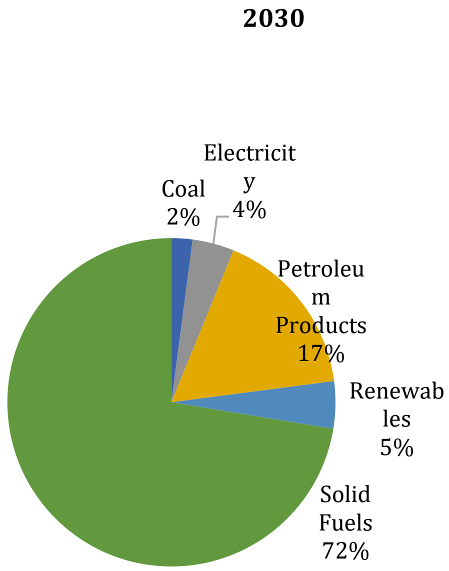


Figure 8-1. Fuel Demand Trend at Low Economic Growth Scenario

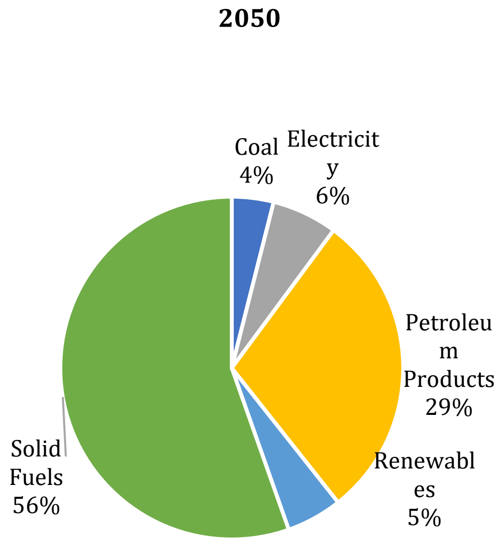
Figure 8-2 shows the energy mix in the total fuel demand which suggests demand for solid biomass is expected to decrease to 72% in 2030 and 56% in 2050 respectively. Compared to 2022, the demand of petroleum products would grow to 29% in 2050 while the electricity demand share would be 4% in 2030 and 6% in 2050 respectively, which signs that there will be a need for some intervention for promotion of electrification and renewable energy.



(a) Total Final Energy Demand = 37 PJ



(b) Total Final Energy Demand = 36 PJ



(c) Total Final Energy Demand = 64 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 25% in 2050 from 73% in 2022 due to shift to more efficient technologies. Meanwhile, the industrial sector's share of energy demand will increase to 23% in 2030 and 48% in 2050, not only because of increasing manufacturing activity but also lack of proper energy efficiency interventions. Whereas the share of energy demands in the commercial sector will nearly triple to 9% in 2050. On the other hand, the share of demand in the transport sector will grow slowly to 5% in 2050 from 3% in 2022. It is therefore crucial to put more focus on improving energy efficiency in the industrial sector as well as in the residential sector as there are still more opportunities for fuel replacement and efficiency improvements.

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

	2022	2025	2030	2035	2040	2045	2050
Agriculture	1.01	1.15	1.52	2.05	2.81	3.94	5.62
Commercial	1.27	1.40	1.75	2.26	3.00	4.08	5.70
Construction and Mining	0.61	0.69	0.91	1.22	1.68	2.35	3.36
Industry	5.73	6.25	8.24	11.11	15.26	21.36	30.48
Residential	27.06	25.52	22.27	19.97	18.26	16.94	15.91
Transport	1.23	1.30	1.47	1.70	2.02	2.48	3.16
Total	**36.92**	**36.31**	**36.16**	**38.31**	**43.03**	**51.16**	**64.24**

(Calculations, 2022)

Figure 8-3 shows the installed power plant capacity required with 30% planning reserve on expected peak load for the study period. The required power plant capacity in 2022 was 79 MW. The future power requirement would be nearly 229 MW in 2030 and 635 MW in 2050 to fulfill the demand of about 1,003 GWh and 2,782 GWh in 2030 and in 2050 respectively.

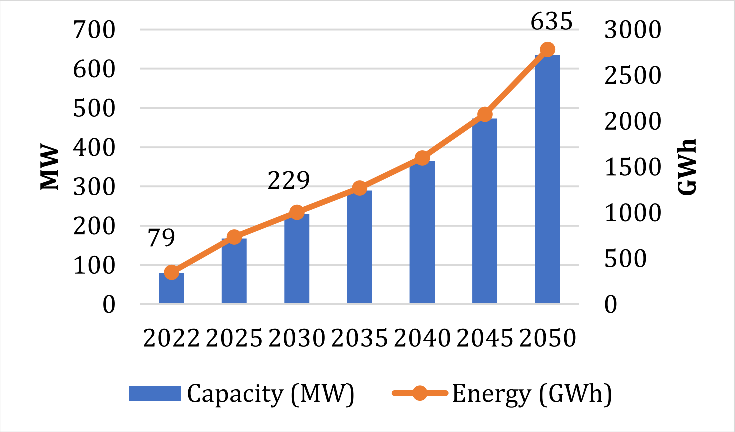


Figure 8-3. Installed Power Plant Capacity Requirement Low Economic Growth Scenario

GHG emissions trend in Reference Economic Growth Scenario is as shown in **Figure 8-**4. GHG emissions would increase from 591 kt in 2022 to 674 kt in 2030 and will reach 1,761 kt in 2050. The GHG emissions would grow at an average growth rate of 4% during 2022-2050. Thus, there will be 3 times growth in GHG emissions in 2050 from its base year and it is mainly attributed to the growing demand in fossil fuels in the Sudurpashchim Province.

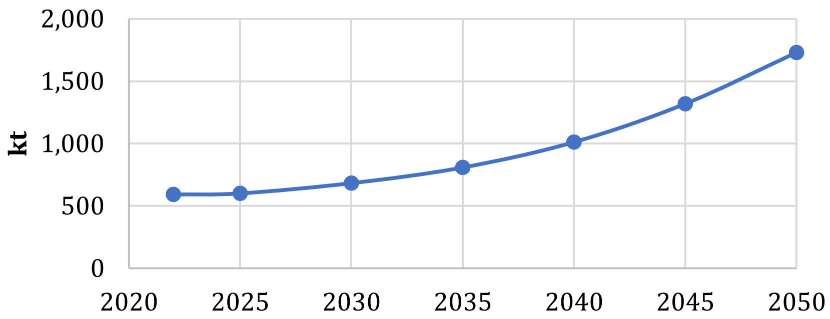


Figure 8-4. GHG emissions at Low Economic Growth Scenario

- **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 reach only about 1.5 times in 2050 with respect to current demand. Meanwhile, the share of renewables is also expected to increase slightly to nearly double in 2050, but on the other hand the net import of fuel in also seen to reach 32% in 2050 from 14% in 2022, all due to the 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 2.5 times by 2050 from the current baseline values in Sudurpashchim Province, although there is no significant improvement in efficiency, the energy intensity remains low, indicating that there might be some intervention needed as well for demand creation in this province.

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

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	13.70	13.27	12.87	13.29	14.54	16.85	20.62
Final electricity demand	kWh/capita	149	174	206	253	318	412	549
Final energy demand	GJ/million NRS	125	108	82	64	53	45	39
Final Electricity Demand	kWh/million NRS	1,367	1,421	1,313	1,223	1,150	1,092	1,048
Total Electricity Used/household	kWh/HH	265	265	265	265	265	265	265
Share of renewable energy in final total energy demand	per cent	6.73%	7.61%	8.76%	9.73%	10.51%	11.08%	11.45%
the ratio of net import to total primary energy supply	per cent	14.39%	15.06%	18.83%	22.78%	26.68%	30.33%	33.15%
GHG emission	GHG in Kg/capita	219	219	240	280	342	434	565

(Calculations, 2022)

8.1.2 High Economic Growth (HIH) Scenario

The following are the major assumptions of this scenario:

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

Table 8-4 below shows the total energy demand for the High Economic Growth case of various fuel types from base year to 2050. The total energy demand in Sudurpashchim Province is expected to remain at the current level of 37 PJ in 2022 till 2030, mainly because of penetration of ICS, while it will be 97 PJ in year 2050 which accounts for 3 folds of increase. The average annual growth rate of energy demand is 3.5% 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*	29.12	28.17	26.61	27.07	30.00	36.81	51.03
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	1.04	1.05	1.08	1.11	1.14	1.17	1.20
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.41	0.47	0.64	0.92	1.39	2.21	3.68
			Grid Electricity	1.04	1.26	1.55	1.99	2.73	4.00	6.29
Non-renewable			Petrol	0.91	0.76	0.85	0.99	1.19	1.52	2.08
			Diesel	3.10	3.41	4.66	6.68	10.04	15.87	26.47
			Kerosene	0.05	0.03	0.04	0.06	0.09	0.14	0.24
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.09	0.09	0.10	0.10	0.11	0.11	0.11
			LPG	0.66	0.68	0.75	0.87	1.05	1.36	1.90
			Coal	0.51	0.58	0.80	1.16	1.76	2.80	4.22
Total				36.92	36.50	37.09	40.95	49.50	65.97	97.23

(Calculations, 2022)

The share of primary solid biomass (fuelwood, agri-residue and animal dung) is high throughout the period and growing at an annual rate of 2% only because of penetration of efficient ICS. 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% per annum each (**Figure 8-5**). Thus, in HIH scenario too, the growth rate in demand for petroleum products will be higher than the demand for solid biomass.

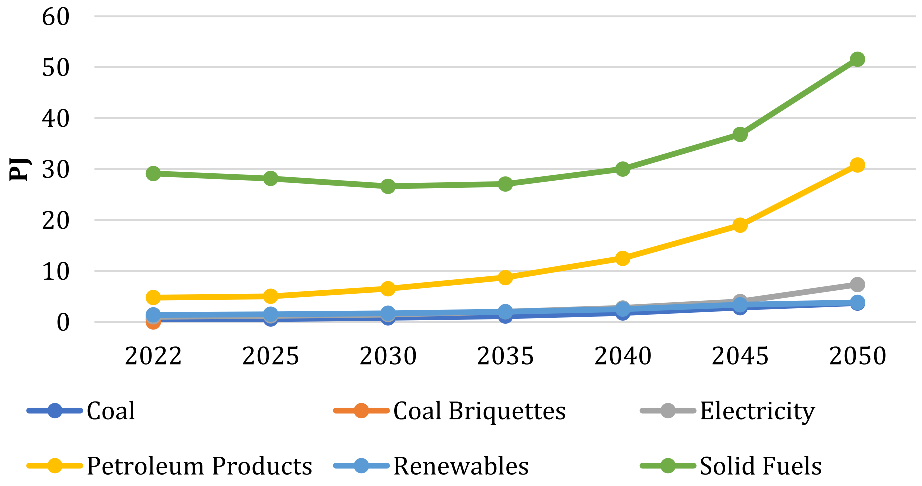
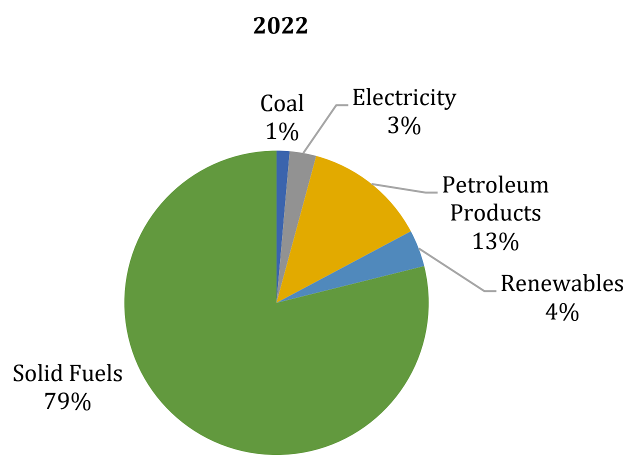
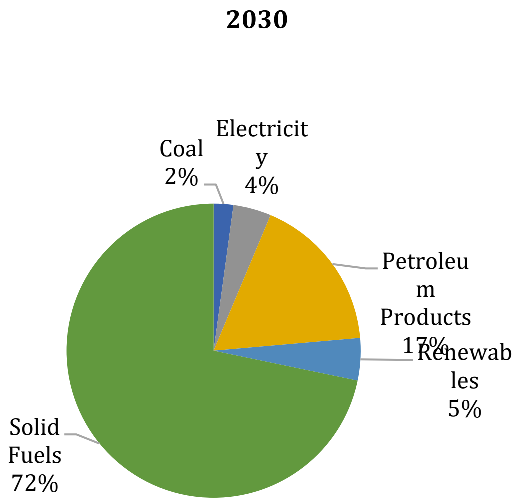


Figure 8-5. Fuel Demand Trend at High Economic Growth Scenario

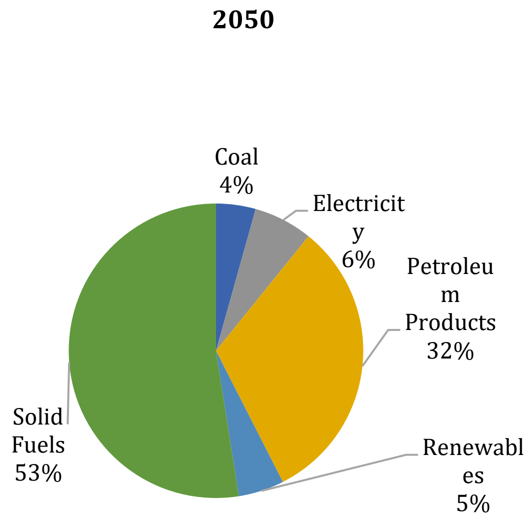
Figure 8-6 shows the energy mix in the total fuel demand for 2022, 2030 and 2050 years. The demand of solid biomass is expected to decrease to 72% in 2030 and 53% in 2050 respectively. Compared to 2022, the share in demand of petroleum products would grow by 6 times, to 32% in 2050. The electricity demand share would be 4% in 2030 and 6% in 2050 respectively thus indicating lower adoption of electric appliances and technologies.



(a) Total Final Energy Demand = 37 PJ



(b) Total Final Energy Demand = 37 PJ



(c) Total Final Energy Demand = 97 PJ

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

Table 8-5 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 16% in 2050, lower than in LOW scenario. Meanwhile, the industrial sector's share of energy demand will increase to 24% in 2030 and 53% in 2050, which are higher than in LOW scenario. Both are consequences of expected higher economic activities in the province. Whereas the share of energy demands in the commercial sector will increase to 10% in 2050. There will be a 5% share 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	1.01	1.17	1.63	2.36	3.57	5.68	9.53
Commercial	1.27	1.425	1.87	2.59	3.80	5.89	9.66
Construction and Mining	0.61	0.70	0.97	1.41	2.13	3.40	5.69
Industry	5.73	6.37	8.81	12.77	19.36	30.82	51.67
Residential	27.06	25.52	22.27	19.97	18.26	16.94	15.91
Transport	1.23	1.31	1.54	1.87	2.38	3.24	4.76
Total	**36.92**	**36.50**	**37.09**	**40.95**	**49.50**	**65.97**	**97.23**

(Calculations, 2022)

Figure 8-7 shows the installed power plant capacity required for the study period. The future power requirement would be 241MW in 2030 and 883 MW in 2050 from current demand of 79 MW in 2022. The electricity demand will grow at the rate of 9.1% with higher economic activities happening.

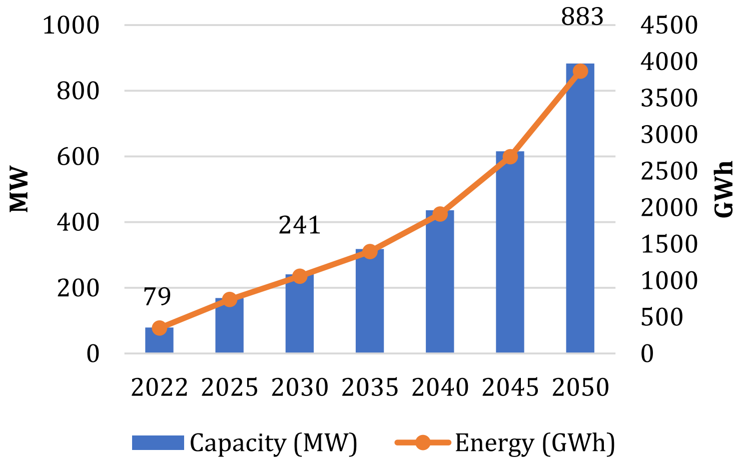


Figure 8-7. Installed Power Plant Capacity Requirement High Economic Growth Scenario

GHG emissions trend in High Economic Growth Scenario is as shown in **Figure 8-8.** GHG emissions would increase to 706 kt in 2030 and can reach 2,840 kt in 2050. The GHG emissions would grow at an average growth rate of 5.7% during 2022-2050, reaching nearly 5 times the current GHG emissions in 2050. This increase is mainly attributed to the high demand for fossil fuels in the Sudurpashchim Province with increased economic activities.

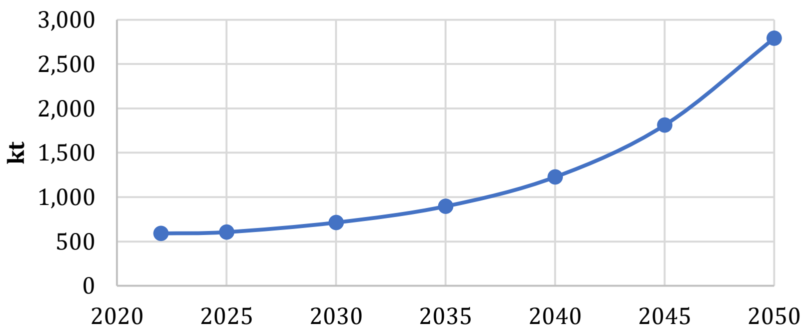


Figure 8-8. GHG emissions at High Economic Growth Scenario

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

Table 8-6 provides energy indicators for the High Economic Growth Scenario, revealing that without any policy intervention in the energy sector, energy demand is projected to double per capita by 2050 compared to the current levels. Concurrently, the share of renewables is expected to rise to 11.5% in 2050 from the current 6.7%. However, the net import of fuel is also projected to increase significantly, reaching 36% in 2050, up from 14% in 2022. This increase can be attributed to the growing demand for carbon-based energy and conventional technologies in economic sectors. Consequently, the importation of carbon-based fuels and their utilization is anticipated to have a substantial impact, leading to a more than fourfold increase in per capita greenhouse gas emissions by 2050 compared to 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	13.70	13.34	13.20	14.21	16.73	21.73	31.20
Final electricity demand	kWh/capita	149	176	217	281	387	568	889
Final energy demand	GJ/million NRS	125	107	79	60	48	40	35
Final Electricity Demand	kWh/million NRS	1367	1411	1289	1185	1104	1044	1001
Total Electricity Used/ household	kWh/HH	265	265	265	265	265	265	265
Share of renewable energy in final total energy demand	per cent	6.7%	7.6%	8.8%	9.8%	10.6%	11.2%	11.5%
The ratio of net import to total primary energy supply	per cent	14.4%	15.2%	19.4%	24.1%	28.8%	33.0%	36.0%
GHG emission	GHG in Kg/capita	219	221	251	311	415	597	911

(Calculations)

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 presented below illustrates the cumulative energy demand for different fuel categories in the reference growth scenario, spanning from the base year to 2050. In Sudurpashchim Province, the total energy demand is projected to undergo significant changes, starting at 37 PJ in 2022 and reaching 36 PJ in 2030. By the year 2050, this demand is anticipated to surge to 76 PJ, marking a twofold increase. The average annual growth rate of energy demand in this reference case stands at 2.6%, with petroleum products and solar electricity emerging as the fastest-growing fuels. This growth is particularly attributed to the province's remote geography, which makes grid expansion more challenging."

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***	29.12	28.09	26.25	26.11	27.82	32.11	40.92
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	**Biogas**	1.04	1.05	1.08	1.11	1.14	1.17	1.20
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		**Solar PV**	0.41	0.46	0.61	0.83	1.18	1.74	2.70
			Grid Electricity	1.04	1.25	1.50	1.85	2.40	3.29	4.78
Non-renewable			**Petrol**	0.91	0.75	0.84	0.96	1.11	1.35	1.72
			Diesel	3.10	3.36	4.42	6.02	8.51	12.56	19.42
			Kerosene	0.05	0.03	0.04	0.05	0.08	0.11	0.18
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.09	0.09	0.10	0.10	0.11	0.11	0.11
			LPG	0.66	0.68	0.74	0.84	0.97	1.19	1.55
			Coal	0.51	0.57	0.76	1.04	1.48	2.21	3.11
Total				36.92	36.34	36.34	38.91	44.80	55.83	75.67

(Calculations)

The proportion of primary solid biomass (including fuelwood, agricultural residue, and animal dung) will maintain a substantial presence over the entire timeframe, expanding at a rate of 1.3% annually. Conversely, petroleum products, experiencing robust growth, are projected to increase at a rate of 6%, while the demand for electricity is expected to follow a similar trajectory, as illustrated in **Figure 8-9.** However, without interventions, the share of electricity is unlikely to reach double-digit figures.

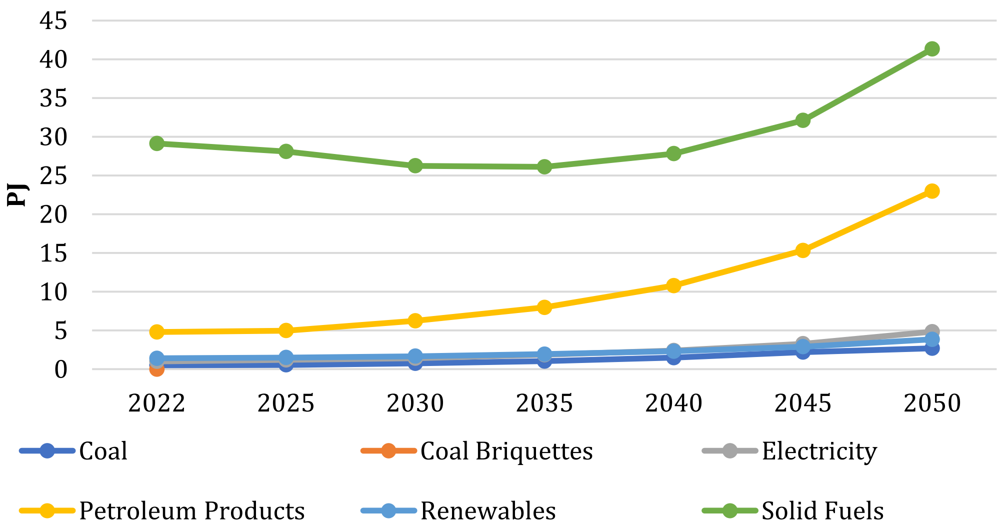
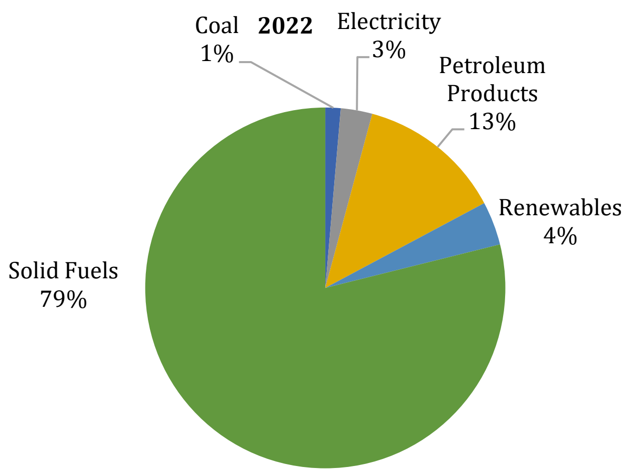
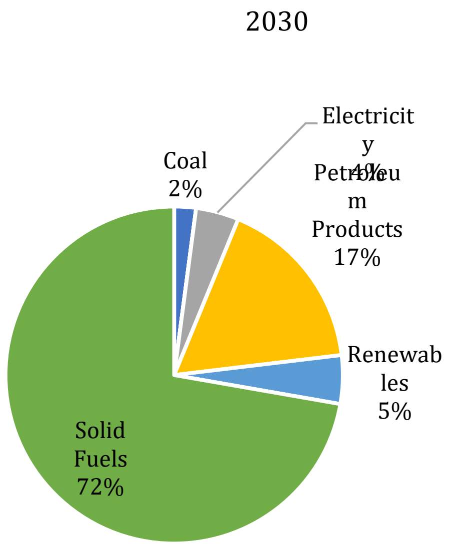


Figure 8-9. Fuel Demand Trend at Reference Economic Growth Scenario

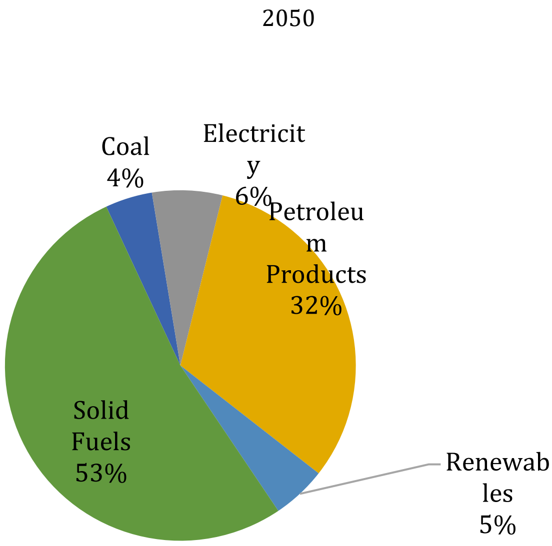
In **Figure 9-10,** the energy mix in the overall fuel demand is depicted for the years 2022, 2030, and 2050. It is anticipated that the utilization of solid biomass will decline, accounting for 72% in 2030 and further decreasing to 53% by 2050. In contrast, the demand for petroleum products is projected to increase significantly, reaching 32% of the total final energy demand in 2050 compared to the 2022 levels. The share of electricity in energy demand is expected to be 4% in 2030, growing to 6% by 2050.



Total Final Energy Demand = 37 PJ



(b) Total Final Energy Demand = 36 PJ



(c) Total Final Energy Demand = 76 PJ

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

Table 8-8 provides insights into the distribution of energy demand across different sectors in this scenario. Notably, the residential sector's portion shrinks from 73% in 2022 to 21% in 2050, primarily due to the widespread adoption of more efficient Improved Cookstoves (ICS) over Traditional Cookstoves (TCS). On the other hand, the industrial sector's share of energy demand is poised to surge, rising to 23% in 2030 and a substantial 50% by 2050, driven by robust economic growth. The commercial sector will also experience a notable uptick, with its energy demand share increasing from the 3% baseline to 9%. Although there will be an overall increase in energy demand, the transport sector's share will rise at a slower pace, yet the actual demand is projected to increase nearly fourfold by 2050 compared to 2022."

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

	2022	2025	2030	2035	2040	2045	2050

Agriculture	1.01	1.16	1.54	2.11	3.02	4.48	6.97
Commercial	1.27	1.40	1.77	2.33	3.21	4.65	7.07
Construction and Mining	0.61	0.69	0.92	1.26	1.80	2.68	4.16
Industry	5.73	6.27	8.34	11.46	16.35	24.31	37.79
Residential	27.06	25.52	22.27	19.97	18.26	16.94	15.91
Transport	1.23	1.30	1.50	1.77	2.16	2.77	3.77
Total	**36.92**	**36.34**	**36.34**	**38.91**	**44.80**	**55.83**	**75.67**

(Calculations)

Figure 8-11 illustrates the persisting reliance on non-renewable energy sources in Sudurpashchim Province under the REF scenario in 2050. The absence of initiatives promoting clean energy results in a continued heavy dependence on biomass and a heightened reliance on imported petroleum products. This trend is projected to significantly increase the demand for fossil fuels by 2050. Questions arise about the sustainability of such a substantial demand for biomass, considering the strain on the province's forests. Furthermore, there are apprehensions about the economic implications of prolonged and substantial imports of fossil fuels, raising doubts about Sudurpashchim Province's ability to endure such a scenario.

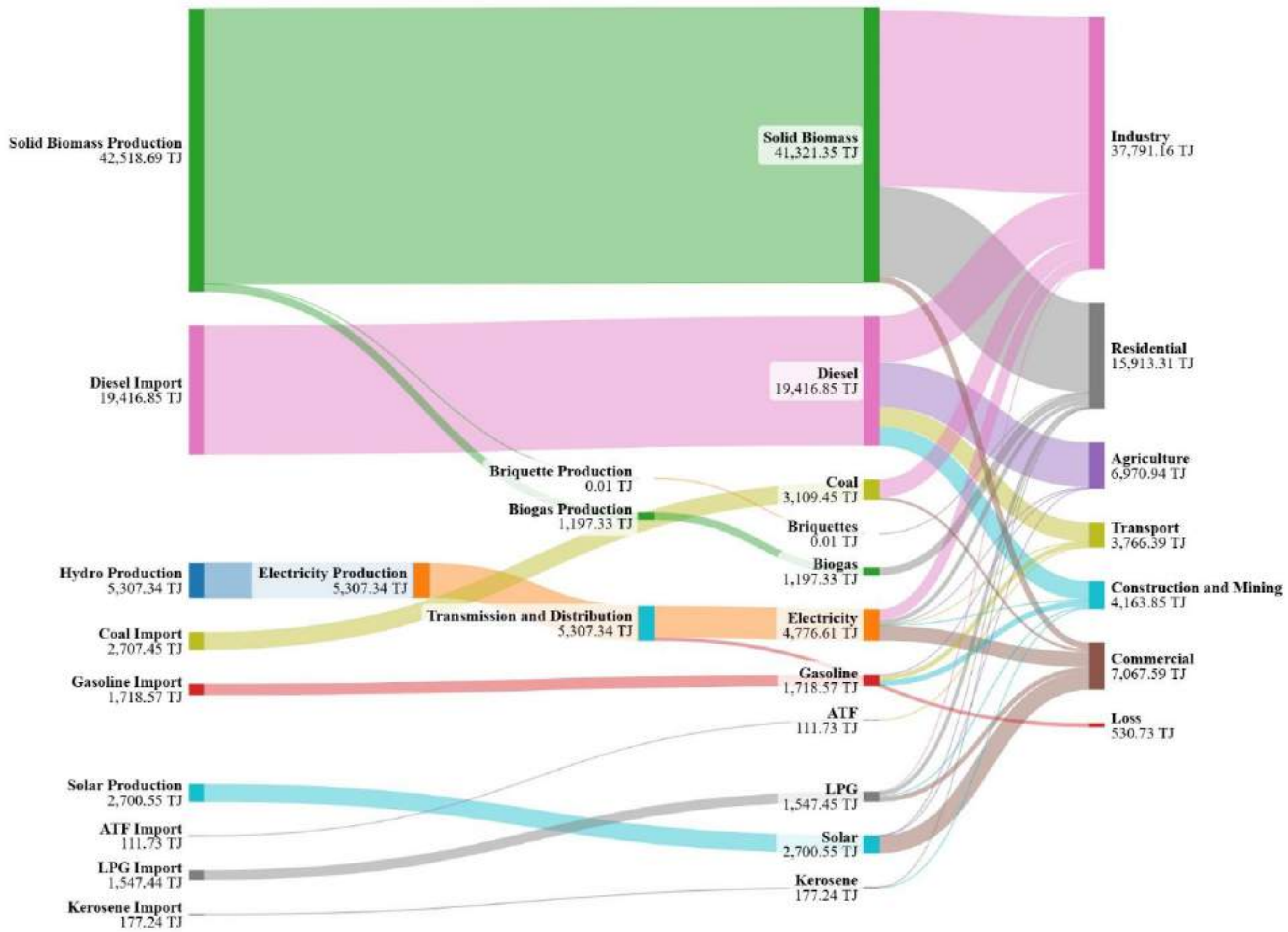


Figure 8-11. Sankey Diagram for Flow of Energy in Sudurpashchim Province for the Reference Economic Growth Scenario in 2050

Sub-sectoral energy demand projections are given in the **Annex.**

Figure 8-12 illustrates the installed power plant capacity needed throughout the study period. The projected power demand is expected to reach slightly over 231 MW by 2030 and then substantially increase to 734 MW by 2050. These capacity figures are directly tied to the electricity requirements, which are estimated at 1,012 GWh in 2030 and a significantly higher 3,215 GWh in 2050. This data provides valuable insights into the growing energy needs and the necessary infrastructure development needed to meet these demands over the specified time frame."

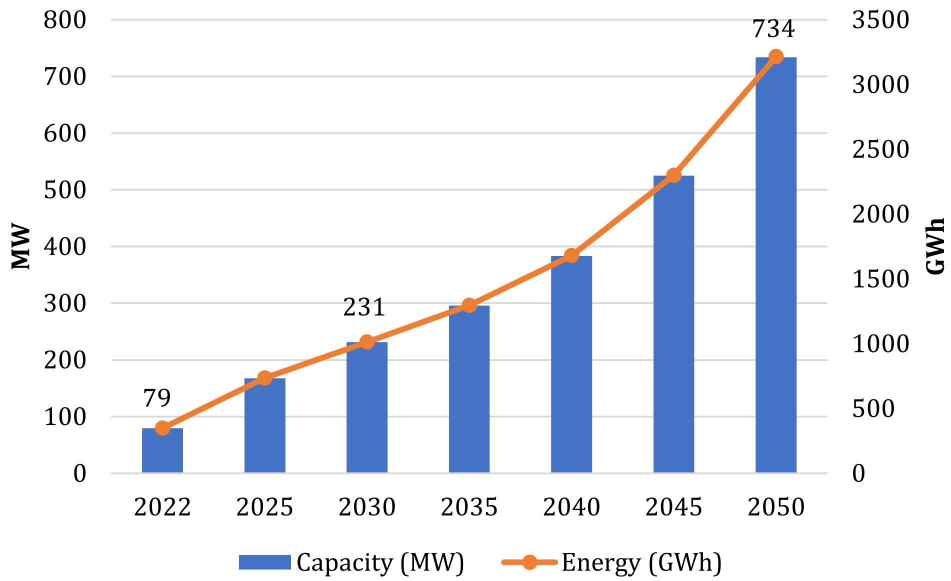


Figure 8-12. Installed Power Plant Capacity Requirement Reference Economic Growth Scenario

GHG emissions trend in Reference Economic Growth Scenario is as shown in **Figure 8-13.** In 2022, these emissions were at 591 kilotons (kt), and by 2030, they are projected to rise to 681 kt. Looking further ahead, in 2050, GHG emissions are estimated to reach 2,137 kt. This translates to an average annual growth rate of 4.7% between 2022 and 2050. In simpler terms, GHG emissions in 2050 are expected to be about 3.6 times higher than the levels in 2022. The primary reason for this significant increase is the growing use of fossil fuels in Sudurpashchim Province.

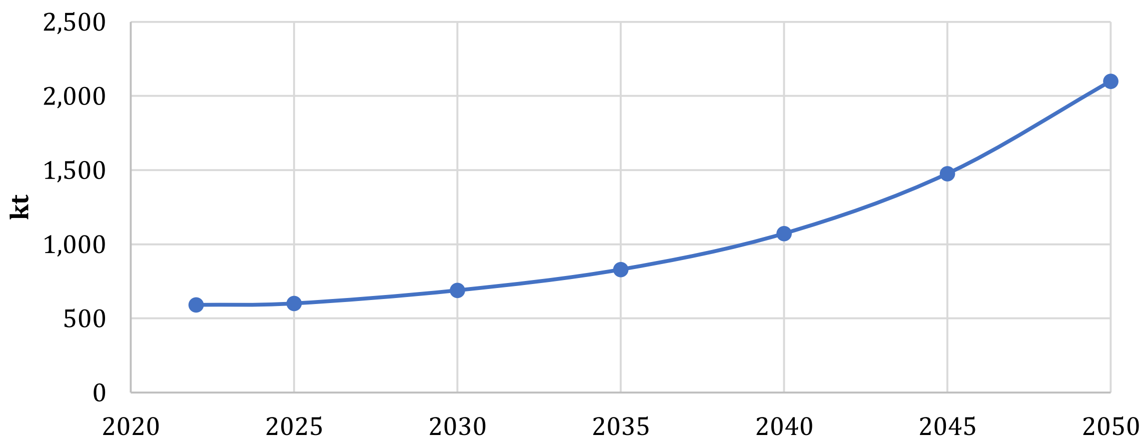


Figure 8-13. GHG emissions at Reference Economic Growth Scenario

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

Table 8-9 provides energy indicators for the Reference Economic Growth Scenario, demonstrating that in the absence of policy interventions in the energy sector, energy demand is projected to increase to nearly double the current demand per capita by 2050. Simultaneously, the proportion of renewable energy sources is expected to grow from 7% to 12% over the coming years. However, the net fuel imports are also predicted to rise, reaching 34% in 2050 from 14% in 2022. This increase is driven by the growing demand for carbon-based energy and traditional technologies in the conventional energy sector. The utilization of imported carbon-based fuels is also anticipated to impact per capita greenhouse gas emissions, increasing to nearly three times the current baseline values, which stand at 220 kg per capita.

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

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	13.70	13.28	12.94	13.50	15.14	18.39	24.29
Final electricity demand	kWh/capita	149	174	208	259	336	460	667
Final energy demand	GJ/million NRS	125	108	81	63	51	43	37
Final Electricity Demand	kWh/million NRS	1,367	1,036	930	838	761	701	655
Total Electricity Used/household	kWh/HH	265	265	265	265	265	265	265
Share of renewable energy in final total energy demand	per cent	6.73%	7.61%	8.76%	9.75%	10.53%	11.10%	11.46%
The ratio of net import to total primary energy supply	per cent	14.39%	15.08%	18.99%	23.15%	27.37%	31.39%	34.46%
GHG emission	GHG in Kg/capita	219	219	243	288	362	486	686

(Calculations)

8.1.4 Sustainable Energy Development (SED) Scenario

In this scenario, all combined policy measures are considered with various technology Interventions. The major focus is on electrification by renewable energy and energy efficiency in various demand technologies. The assumptions are in line with the various published reports and documents of Nepal Governmental agencies, IEA, IRENA, Paris Agreement, NPC's SDG roadmap, NDC 2020 targets for 2030, Nepal's Long-Term Strategies for Net Zero Emission by 2045 and other international energy and emissions-related programs.

The following are the major assumptions of this scenario.

- GDP growth rate according to reference case i.e. 6.96%.
- The shares of energy technologies vary in line with intervening strategies which are given below.

Agriculture:

- 60% Electrification, 40% solar in water pumping by 2050
- 100% electrification in farm machineries by 2050

Commercial sector

- 100% electrification in lighting and electrical appliances by 2050
- 25% 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 others
  - 100% electrification by 2050
- Process Heat
  - 30% electrification, 70% alternative clean fuel by 2050

Residential sector:

- Rural cooking and water heating: 30% electric, 40% ICS and 30% LPG by 2050
- Rural others: 30% electrification, 30% LPG, 40% fuelwood by 2050
- Rural: 100% electrification in rest
- Urban cooking and water heating: 50% electrification, 30% LPG by 2050
- Urban others: 50% electrification, 30% LPG by 2050
- All others to be fully electrified by 2050.

Table 8-10 provides the projected demands for different fuels in this scenario. According to the data, the total energy demand is estimated to be 26 PJ in 2030 and 62 PJ in 2050. When we consider individual energy demand, per capita energy demand is anticipated to be 20 GJ in 2050 in the SEDS. However, in the Reference Economic Growth Scenario, it is expected to be slightly higher at 24 GJ. This comparison highlights the differences in energy demand between the two scenarios, with the SEDS focusing on sustainability and the REF Scenario emphasizing economic growth without intervention. Thus, the energy demands in SDES is anticipated to grow at rate of 1.9% vs 2.6% in REF 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*	29.12	22.40	15.47	15.85	16.74	18.67	22.26
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	1.04	0.94	0.77	0.59	0.41	0.21	0.00
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.41	0.47	0.63	0.87	1.25	1.87	2.93
			Grid Electricity	1.04	1.75	3.09	5.12	8.20	13.30	22.35
Non-renewable			Petrol	0.91	0.69	0.67	0.66	0.68	0.75	0.94
			Diesel	3.10	3.13	3.59	4.16	5.29	7.09	9.85
			Kerosene	0.05	0.03	0.04	0.05	0.08	0.11	0.18
			Furnace Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			ATF**	0.09	0.09	0.10	0.10	0.11	0.11	0.11
			LPG	0.66	0.77	0.98	1.22	1.47	1.75	2.04
			Coal	0.51	0.55	0.67	0.85	1.12	1.30	1.38
Total				36.92	30.81	26.02	29.49	35.33	45.16	62.03

(Calculations)

In this scenario, the overall energy demand is projected to increase at a rate of 1.9% per year, while electricity demand experiences substantial growth, averaging nearly 12% annually from 2022 to 2050 (**Figure 8-14**). When compared to other energy sources, electricity demand is expected to become almost equal to the demand for solid biomass. The demand for primary solid biomass, which includes fuelwood, agricultural residue, and animal dung, is anticipated to decrease by approximately 1% each year over the same period. This decline is attributed to interventions promoting clean energy technologies across various major sectors. Additionally, policy measures aimed at reducing petroleum consumption, especially in residential, industrial, and transport sectors, lead to a significant decrease in its demand in the coming years. The adoption of modern renewable energy sources is expected to grow at a rate of 2.3% per year throughout the analysis period.

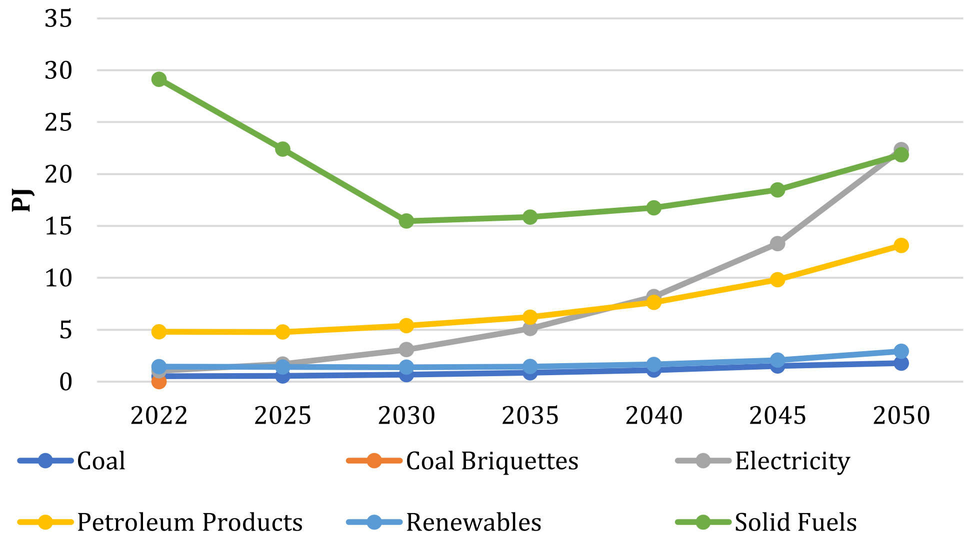
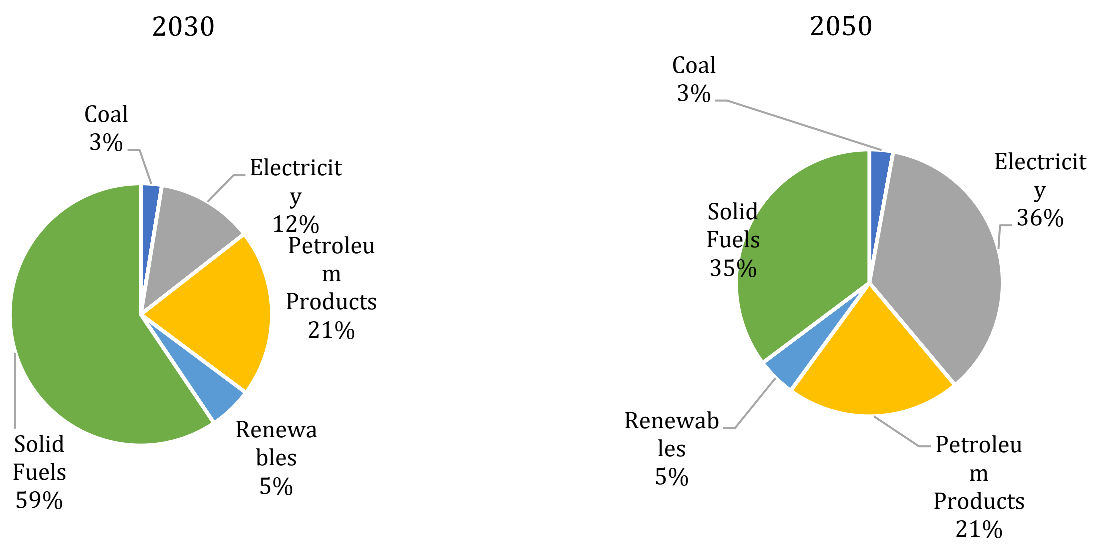


Figure 8-14. Fuel Demand Trend at Sustainable Energy Development Scenario (SEDS)

Figure 8-15 illustrates the composition of energy sources in the overall energy demand for the years 2030 and 2050. During this period, the demand for solid fuels is projected to decline to 59% in 2030 and is expected to further decrease to 35% in 2050. Nonetheless, due to the remote nature of certain areas in the province, the use of biomass remains a viable, cost-effective option in some locations. Electricity demand is expected to account for 12% of the energy mix in 2030 and then increase to 36% by 2050. Meanwhile, the demand for petroleum products is predicted to represent 21% of the total energy demand by the end of this period.



(a) Total Final Energy Demand = 26PJ (b) Total Final Energy Demand = 62PJ

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

Table 8-11 provides a breakdown of energy demand across various sectors within this particular scenario. Notably, the residential sector's portion decreases significantly, dropping to 17% by 2050 from a dominant 73% in 2022. On the other hand, the industrial sector's share of the energy demand is set to increase, reaching 31% by 2030 and a substantial 54% by 2050. Meanwhile, the commercial, agriculture, and transport sectors will account for 10%, 8%, and 5% of the total energy demand, respectively, by the year 2050. These changes in sectoral energy demand distribution signify a notable shift in the energy landscape and its utilization over time.

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

	2022	2025	2030	2035	2040	2045	2050
Agriculture	1.01	1.08	1.28	1.53	2.13	3.19	4.99
Commercial	1.27	1.30	1.51	2.03	2.83	4.10	6.22
Construction and Mining	0.61	0.69	0.92	1.26	1.80	2.68	4.16
Industry	5.73	6.19	8.05	10.82	15.09	21.91	33.25
Residential	27.06	20.29	12.88	12.27	11.63	10.94	10.21
Transport	1.23	1.26	1.38	1.56	1.85	2.34	3.19
Total	**36.92**	**30.81**	**26.02**	**29.49**	**35.33**	**45.16**	**62.03**

(Calculations)

Figure 8-16 provides a visual representation of the noteworthy transformations expected in Province's energy dynamics by 2050, as per the SED Scenario. The illustration highlights a significant reduction in reliance on solid biomass and a decreased necessity for importing fossil fuels to fulfill crucial energy requirements. This transition signals a pivotal change in the energy paradigm of the Sudurpashchim Province, foreseeing a predominant reliance on clean and renewable sources for electricity demand. Beyond fortifying energy security, this evolution underscores a commitment to regional sustainability, aligning with environmentally conscious practices for a resilient energy future.

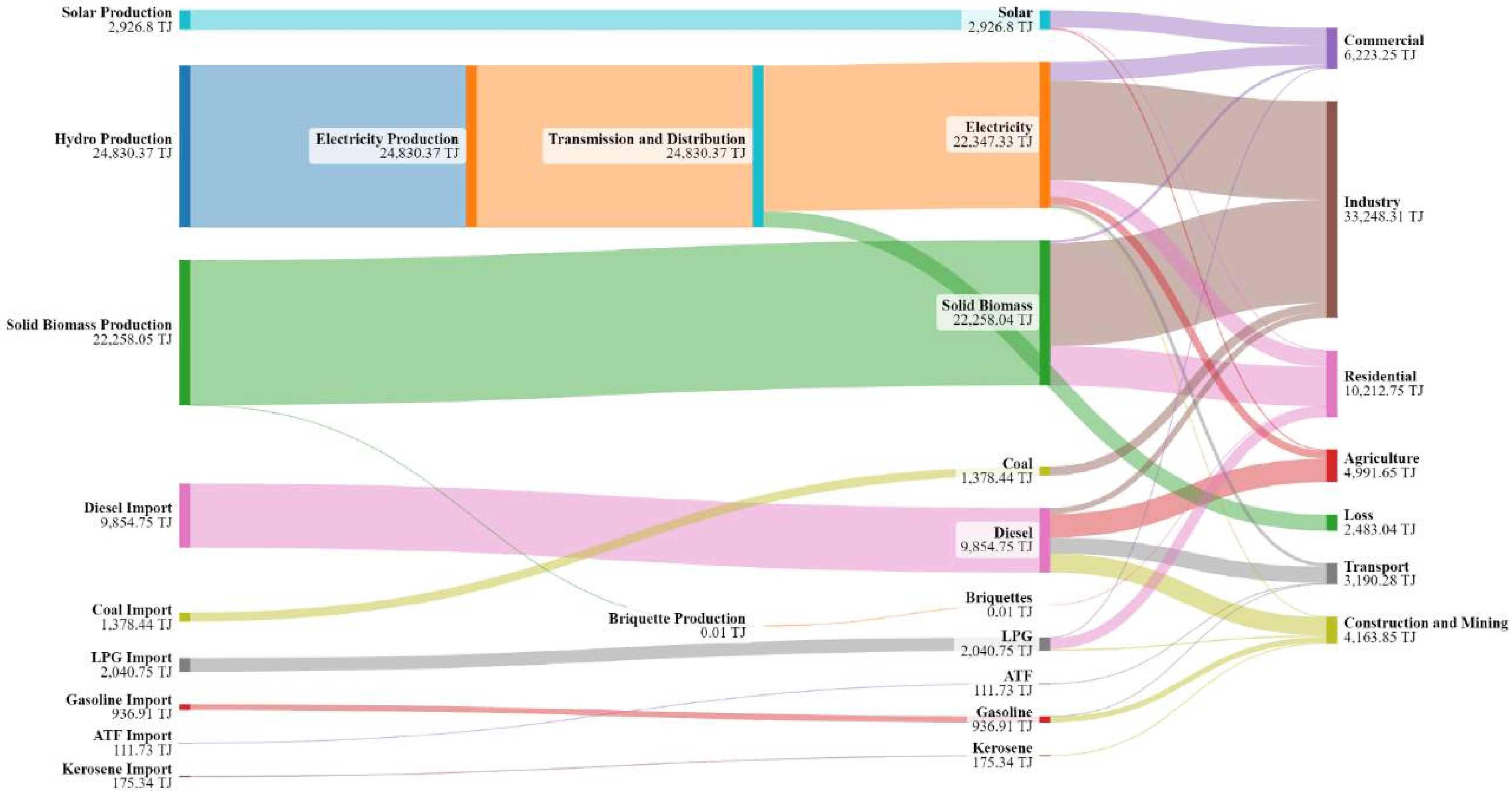


Figure 8-16. Sankey Diagram for Flow of Energy in Sudurpashchim Province for the Sustainable Energy Development Scenario in 2050

The installed power plant capacity requirement in this scenario is as shown in **Figure 8-17.** By 2030, Sudurpashchim Province is expected to require a power plant capacity of 439 MW, a figure that is set to escalate dramatically to 2,918 MW by 2050. This substantial increase, more than fourfold the requirement in the reference case for 2050, is primarily driven by extensive electrification efforts. The corresponding electricity demand is projected to be 1,924 GWh in 2030, surging to a substantial 12,780 GWh by 2050. These figures reflect the significant transformation in power generation and consumption as electrification becomes more widespread and prominent in the region if proper intervention is taken.

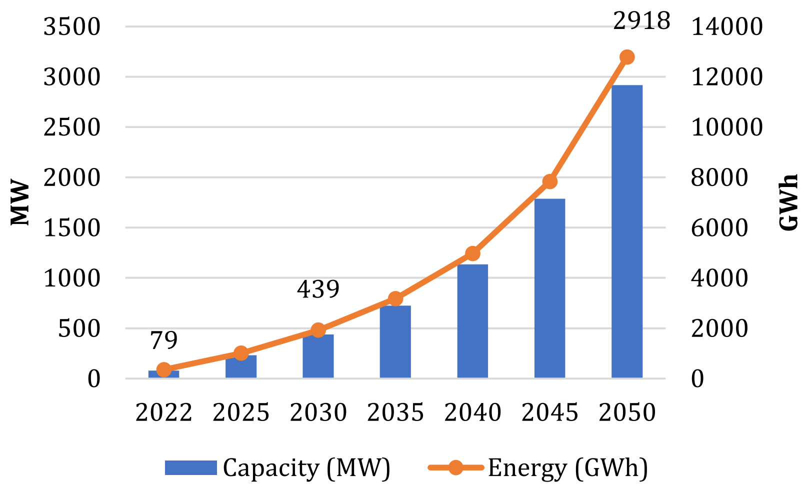


Figure 8-17. Power Plant Capacity Requirement in Sustainable Energy Development Scenario (SEDS)

GHG emissions trend in Sustainable Energy Development Scenario (SEDS) is shown in **Figure 8-**18. GHG emissions are projected to decrease from 591 kt in 2022 to 540 kt in 2030 and then increase to 1,196 kt in 2050. This represents an average annual growth rate of 2.5% between 2022 and 2050. When compared to the Reference Economic Growth Scenario, SEDS is expected to achieve an 81% reduction in GHG emissions by 2050. This substantial reduction is primarily attributed to the emphasis on electrification through renewable energy sources and the adoption of energy-efficient practices across all sectors. In this context, the level of economic development has a reduced impact on GHG emissions. These efforts align with both national and international programs aimed at achieving Sustainable Development Goals (SDGs) and mitigating the effects of climate change. (Harvey et al., 2018; IEA, 2017; UN, 2015; IEA, 2020; LIFE-AR, 2019; NPC,2016; WB,2020).

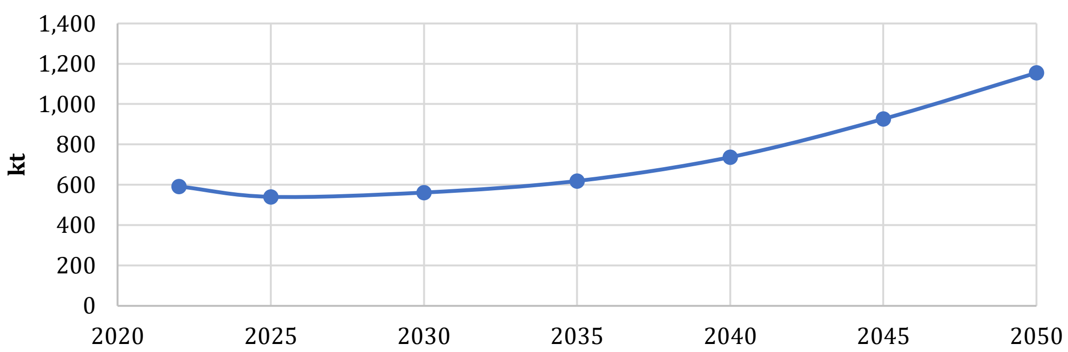


Figure 8-18. GHG emissions at Sustainable Energy Development Scenario (SEDS)

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

Table 8-12 provides energy indicators for the policy scenario, known as SEDS, highlighting the notable effects of strategic interventions within the energy sector. Notably, per capita final energy demand in 2050 is 82% of that in the Reference Economic Growth Scenario, underscoring the success of these interventions. Furthermore, the shift towards clean and renewable electricity resources is evident, with per capita electricity consumption exceeding 2,000 kWh. The influence of energy efficiency measures is discernible in per capita energy demand and energy required per million units of GDP. Additionally, the share of fuel imports diminishes, accounting for 23% of the total energy in 2050, compared to 34% in the reference scenario. Conversely, the utilization of national resources increases with the growing adoption of renewables, reaching 41% in 2050, a significant improvement from the mere 11% seen 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	13.70	11.26	9.26	10.23	11.94	14.87	19.91
Final electricity demand	kWh/capita	149	225	368	577	887	1387	2253
Final energy demand	GJ/million NRS	125	92	58	48	40	35	31
Final Electricity Demand	kWh/million NRS	1,367	1,445	1,923	2,317	2,599	2,836	3,065
Total Electricity Used/household	kWh/HH	265	348	487	625	764	903	1041
Share of renewable energy in final total energy demand	per cent	6.73%	10.24%	17.26%	22.33%	27.88%	34.04%	40.74%
The ratio of net import to total primary energy supply	per cent	14.39%	17.06%	23.27%	23.91%	24.73%	24.62%	23.37%
GHG emissions	GHG in Kg/capita	219	198	192	212	248	306	384

(Calculations)

8.2 Comparative Analysis

Figure 8-19 presents the final energy demand for both the reference (REF) and the policy scenarios, known as SEDS, highlighting the evident effects of fuel transition and enhanced energy efficiency. The utilization of these strategies, coupled with a reduced growth rate of 1.9% as opposed to the 2.6% in the REF scenario, results in a noteworthy reduction of nearly 28% in total final energy demand by 2030 and approximately 18% energy savings in 2050. While the energy savings percentage may not appear exceptionally high, it's important to recognize that the substantial transformation occurs in the energy mix itself, shifting from reliance on imported petroleum fuels to the utilization of locally sourced and cleaner energy options.

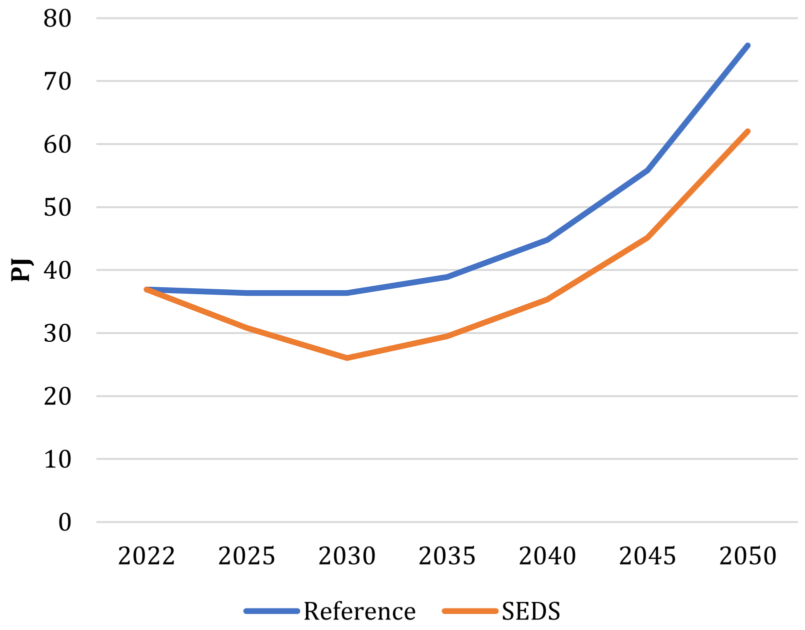


Figure 8-19. Total Final Energy Demand in Sudurpashchim Province

We observe a comparable pattern in per capita energy demand, as depicted in **Figure 8-20,** with a notable decrease in energy intensity. In the SED scenario, energy intensity experiences a growth rate of just 1.3%, primarily due to the implementation of energy efficiency measures. In contrast, without these actions, energy intensity in the REF scenario would grow at a rate of 2.1%. This underscores the positive impact of energy efficiency interventions in curbing the growth of energy demand per capita.

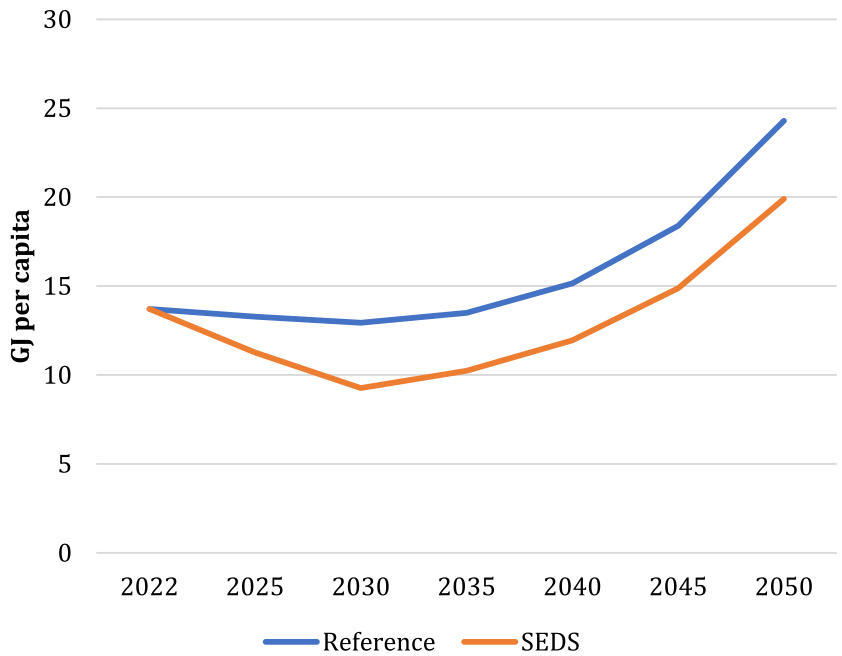


Figure 8-20. Final Energy Demand per capita in Sudurpashchim Province

Figure 8-21 illustrates a comparison of electricity demand between scenarios, showcasing the significant differences. In the Sustainable Energy Development Scenario (SEDS), there is a notable surge in total electricity consumption, driven by extensive electrification efforts in various sectors. This results in a substantial increase, with overall per capita electricity demand reaching 2,253 kWh in 2050. Simultaneously, household electricity demand climbs to 1,041 kWh per household. However, it is important to note that this figure falls short of meeting the Tier-5 criteria, which is set at 3,000 kWh per household as defined by the World Bank (WB/ESMAP, 2019). Despite this, the growth in electricity access signifies a rising demand for domestically generated hydroelectric power.

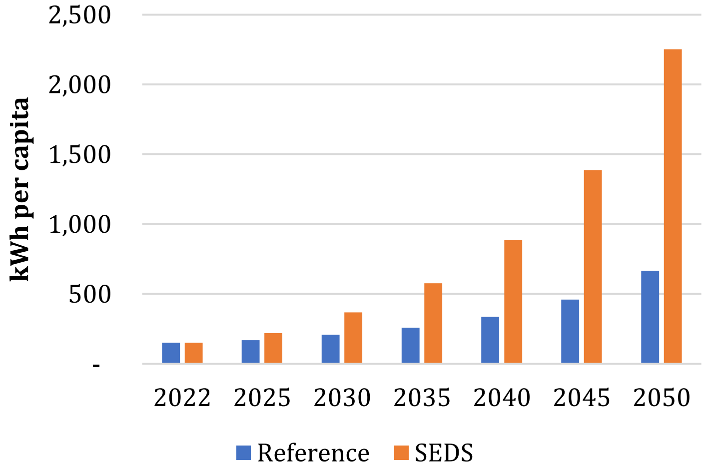


Figure 8-21. Electricity Demand per capita in Sudurpashchim Province

As a result of the implementation of electric technologies and advancements in domestic electricity production, particularly from hydropower and other renewable sources, there is a noticeable surge in the proportion of renewable energy, as depicted in **Figure 8-22.** The share of clean and renewable energy is anticipated to climb from 7% in 2022 to 41% in 2050, a substantial leap compared to the 11% projected in the REF scenario. This transformation hinges on the successful development of hydropower and solar PV generation capacities at both the provincial and national levels.

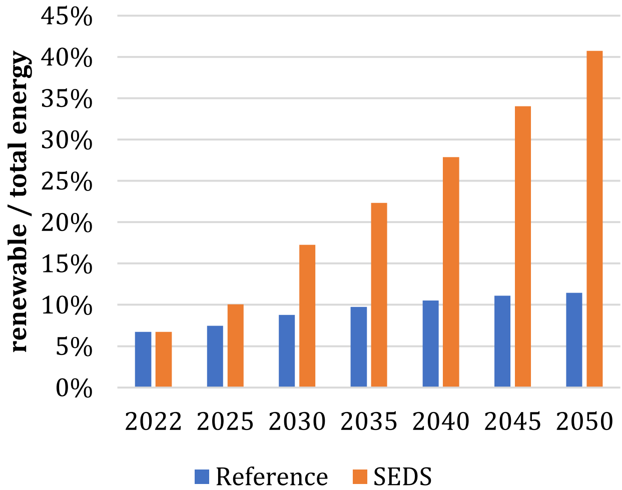


Figure 8-22. Renewable Energy to Total Energy Demand Ratio in Sudurpashchim Province

The impact of energy development and production from domestic sources alleviates the burden of fuel dependency, as illustrated in **Figure 8-23.** Up until 2035, the proportion of net energy imports to total energy remains relatively high due to the significant reduction in total energy demand in the SEDS scenario, primarily attributed to the rapid adoption of efficient cooktops, which account for a significant share of energy demand. However, post-2035, the net import ratio in SEDS decreases, signifying a reduction in energy dependency.

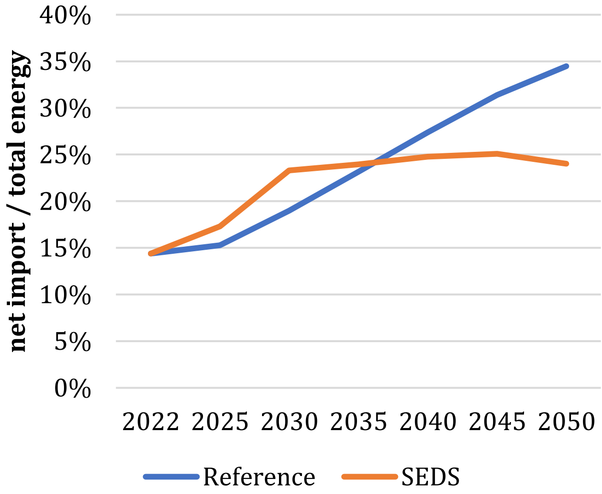


Figure 8-23. Petroleum Import to Total Energy Ratio in Sudurpashchim Province

Figure 8-24 depicts the influence of policy measures promoting clean energy on GHG emissions. In contrast to the Reference Economic Growth Scenario, where emissions were on a trajectory of 4.7% annual growth, the policy interventions lead to a significantly lower growth rate of 2.5%. This translates into a noteworthy reduction of GHG emissions by 21% in 2030 and a substantial 44% by 2050. This decrease in GHG emissions is advantageous not only from a climate perspective but also from two other significant standpoints. Firstly, it positively impacts public health, as carbon-based fuels emit pollutants that directly harm the health of local populations and users. Secondly, it has economic implications by allowing the monetization of emission reductions through carbon trading.

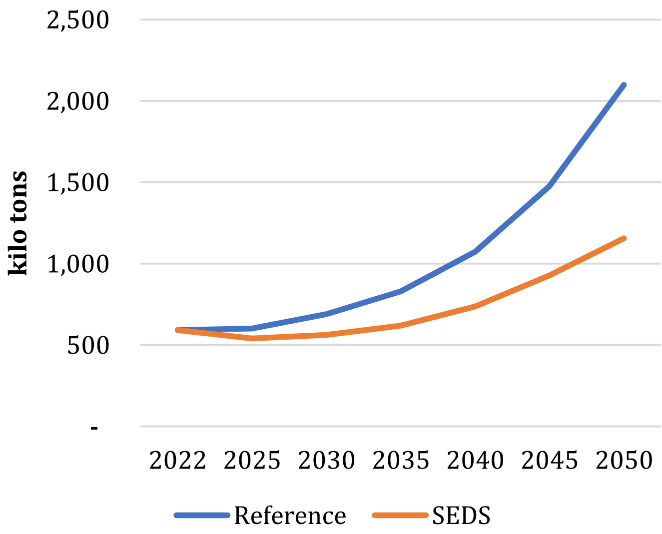


Figure 8-24. GHG emissions in Sudurpashchim Province

In order to fulfill the greater portion of the energy needs in the SEDS and to accomplish the aforementioned development objectives, the establishment of hydropower facilities becomes indispensable. In comparison to the reference case, the SEDS necessitates approximately 439 MW of hydro power plant capacity by 2030, marking a 100% increase. Furthermore, to accommodate this demand, an even more substantial growth is anticipated, with up to four times the additional power plant capacity, totaling 2,918 MW, required by 2050, as depicted in **Figure 8-25.**

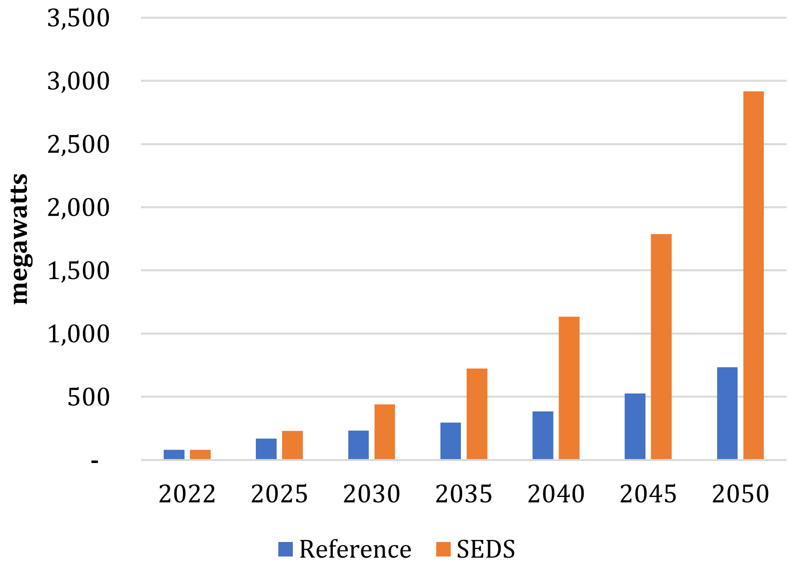
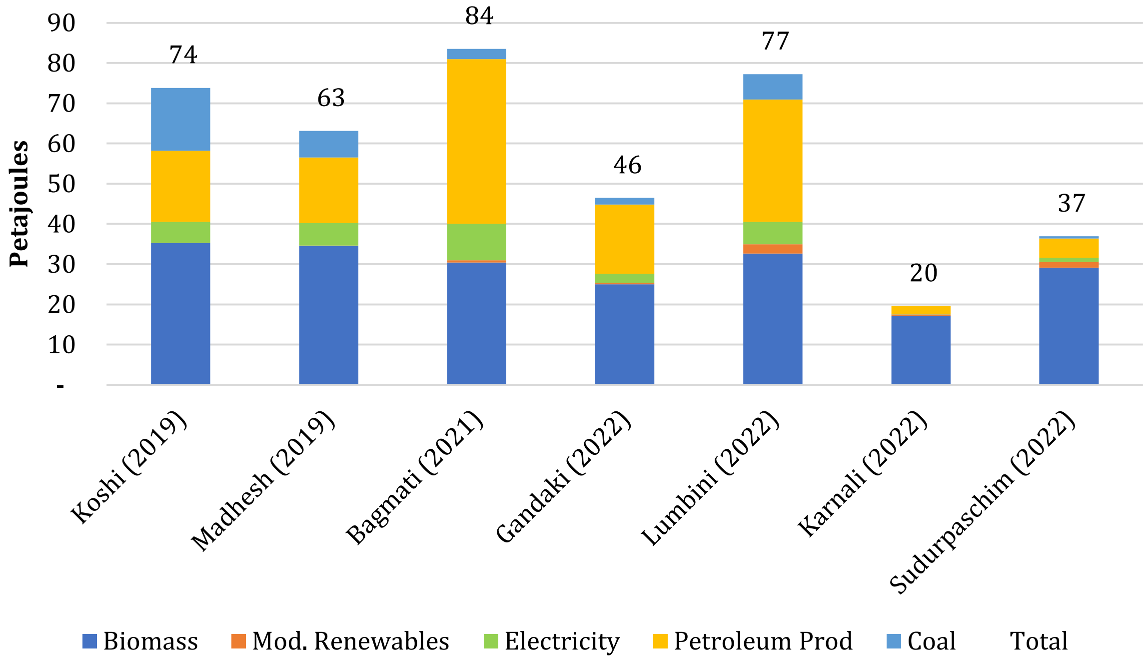


Figure 8-25. Hydro power plant capacity requirement in Sudurpashchim Province

8.3 Provincial Comparison

Comparing the energy consumption of Sudurpashchim Province with the rest of the province, the total consumption of the province is second lowest among the seven provinces. One of the major reasons for lower consumption in Sudurpashchim Province is the low number of industries as well as lower commercial activities in compared to more economically developed provinces. Moreover, the overall population of the province is also lower, causing a lower demand for energy (**Figure 8-26).**



(WECS, 2019, 2021) (Survey, 2023)

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

The comparison of energy consumption per GVA of all seven provinces is shown in **Table 8.13.** It shows that Gandaki has the highest industrial energy per GVA showing lower energy efficiency as well as the use of diesel generators for electricity. Meanwhile, Karnali has the least industrial energy per GVA indicating lower energy-intensive industries in the province. Similarly, commercial energy per GVA of Gandaki Province and that of Lumbini Province is comparable and is high compared to the other provinces indicating the lower efficiency owing to a large share of primary solid fuels used in the commercial sector. Comparing the agriculture energy intensity, Lumbini has the highest intensity showing energy-intensive activities compared to the other provinces. Similarly, energy consumption per capita in residential sector is the highest in Sudurpashchim Province due to the large share of primary solid fuels used for cooking and other residential activities. Energy consumption per capita in the transport sector of Koshi Province is the highest and is comparable to Bagmati, Lumbini, and Gandaki.

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

	Energy consumed per provincial gross value addition (KJ/GVA)						
Economic sector	**Koshi**	**Madhesh**	**Bagmati**	**Gandaki**	**Lumbini**	**Karnali**	**Sudurpashchim**
Agriculture	2.74	4.39	4.85	11.46	29.33	4.40	9.98
Commercial	7.78	9.18	7.23	18.18	16.22	11.07	8.20
Industrial	871.98	602.51	444.4	1,304.09	738.55	183.01	441.93
Construction & mining	14.50	11.30	14.59	19.89	53.26	14.85	24.92
	Energy consumed per capita (GJ/capita)						
Residential	5.97	6.37	5.03	7.84	5.64	9.93	10.04
Transport	1.48	0.94	1.44	1.28	1.33	0.53	0.46

(WECS, 2019, 2021) (Survey, 2023)

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 Sudurpashchim Province. **Table 9-1** shows the total investment cost for supply technologies in 2022 constant prices compared to the GDP under respective years.

9.1 Capital Investment

In REF scenario, the gross investment share in supply technologies is around 1 % of GDP on average. In SED scenario, new and efficient technology interventions are done. To achieve the sustainable developments goals, capital investment should increase from current less than 1% of GDP to 9% by 2030 and 12% by 2050 respectively. The high investment in SED scenario is mainly due to the investments required in hydropower plants to meet the growing electricity demand because of electrification in all major end uses. These figures can be accounted for the large-scale investment required in hydropower development and industrial capital costs (**Table 9-**1).

In the case of Sudurpashchim Province, which has natural resources and feasibility for development of hydropower plants, the province needs to invest in 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 isolation hours of the day.

Table 9-1: Total Technology Cost for Different Scenarios

	2022	2025	2030	2035	2040	2045	2050
Investment in the REF scenario in NR billion	0.46	3.17	5.44	8.12	11.57	16.40	24.11
Capital Investment as %of GDP	0.15%	0.94%	1.22%	1.32%	1.32%	1.26%	1.19%
Investment in the SEDS scenario in NR billion	0.46	15.97	42.62	74.97	115.07	168.62	247.52
Capital Investment as % of GDP	0.15%	4.75%	9.54%	12.20%	13.13%	12.95%	12.22%

(Calculations)

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

9.2 The Marginal Abatement Cost

GHG emissions for reference scenario and SEDS scenario is shown in **Figure 9-1**. It shows that there is quite a reduction of GHG emissions in SEDS scenario. In 2030, the reduction of emission compared to that of base case scenario is 21%, and 44% in 2050. This considerable reduction of GHG emission accounts for efficient and modern technology.

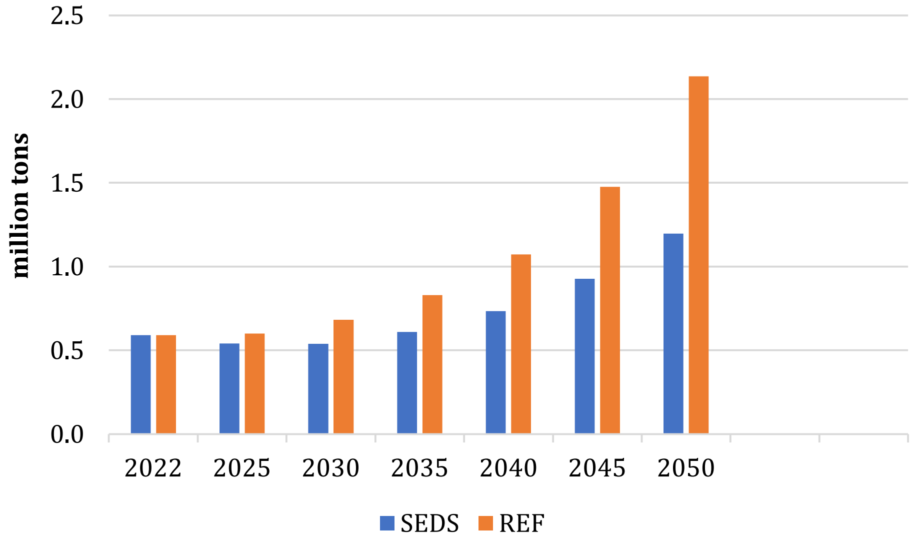


Figure 9-1. GHG Emission for Different Scenarios

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.

Table 9-2: Marginal Abatement Cost

	2025	2030	2035	2040	2045	2050
Incremental Investments (Billion Rs.)	12.80	37.19	66.85	103.50	152.22	223.41
GHG abated (kt)	59.05	141.84	219.02	337.81	547.82	940.64
MAC ('000 NPR/ton of CO2e)	216.72	262.17	305.21	306.38	277.86	237.51

(Calculations)

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

9.3 Net Fuel Import Cost

Figure 9-2 shows the implication of SEDS scenario in terms of saving in net import of petroleum fuels. It is seen that the saving is substantial under the SEDS scenario counting over 4 billion NRs in 2030 and 88 billion NRs in 2050 from that of REF scenario. All the costs incurred are at constant price of 2022. These cost benefits can be invested in development of the electricity generation and distribution system for quality supply of the energy. Comparing the savings to the investment required for power plant development, the savings can account for more than 10% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute nearly 40% 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 highlight the need for proper energy policy in the future. Furthermore, detailed analysis of the strategic actions plans for investment from cost savings needs to be carried out for proper implementation and achievement of the clean and energy efficient targets.

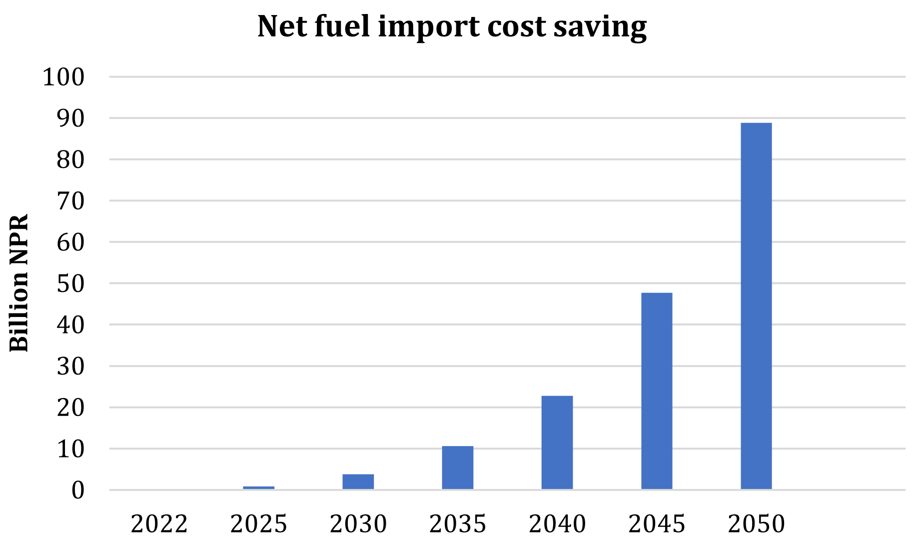


Figure 9-2. Net Fuel Import Cost Savings

9.4 Carbon Trading

In addition to savings from imports of fuels and the value addition to national economy by trading of electricity produced within the nation's boundary, additional economic benefits can also be obtained from carbon trading. The significant abatement of GHG emissions in SEDS compared to REF scenario can be traded as per international carbon pricing of $10. The benefit from carbon trading is as shown in **Table 9-3.**

Table 9-3: Carbon Trading Benefits

	2025	2030	2035	2040	2045	2050
Carbon trading benefits (billion Rs)	0.35	0.70	1.46	3.24	2.43	5.39

(Calculations)

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

10 Limitations and Constraints of the Survey

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

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

11 Conclusions and Policy recommendations

In the context of Nepal and especially the Sudurpashchim Province, energy planning and research are critical for socioeconomic development. The updated database on the energy sector is essential for energy planning and energy policy development. The database highlights key issues that need to be addressed at the provincial levels, primarily the changing energy demands and challenges in adopting an environmentally friendly energy supply. The overarching goal of this report is to help in formulating energy security and to facilitate economic development, promote environmental sustainability, mitigate climate change, and expand access to electricity and modern clean energy to households in all parts of the province.

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

In the year 2021/2022, the primary sample survey shows that the total final energy consumption of the Sudurpashchim Province was 36,919 TJ which accounts for 13.7 GJ per capita. This energy demand per capita seems to be slightly lower than the national average from previous studies. The shares of energy consumption in economic sectors of the Sudurpashchim Province indicate some differences from the national level energy consumption pattern. Residential and Industrial sectors consume 73% and 16% of total energy consumption respectively. The share of energy consumption in the industrial sector, compared to the national level, is higher in the province. Transport sector demand is at 3% and so is in commercial sector is (3%). The final energy consumption in the agriculture sector stands at 3% which is slightly higher than the national level from the previous studies and remaining form construction and mining sector (2%). As for energy consumption by fuel types, the use of biomass is very high at around 79%. Petroleum products comprise 13% of the total energy consumed in the province, coal is 1%, and electricity is 3%. Modern renewables account for 4% of the total energy and they are mostly from biogas plants.

As per ecological regions, Sudurpashchim Province has three regions – Terai, Hills, and Mountain regions. The Terai region has the highest energy consumption with 46% of the total consumption in the province, which is followed by hilly regions with 31%. The mountain region is at 18%, and the rest is consumed in the transportation and construction, and mining sectors, at 3% and 1% respectively. The Terai, Hilly, and Mountain regions consume fuelwood at 35%, 40%, and 25% respectively of the total fuelwood consumed in the province. Fossil fuels and electricity consumptions in the Terai region are highest which is understandable because of the concentration of industries and population within the region.

The forest area and potential fuelwood production in the current situation show potential production of 1,963.9kilo tons/year in the Sudurpashchim Province. There is potential production of 3,760 thousand GJ of energy from Biogas in the province while the total potential energy produced from agricultural waste is 29.94 million GJ. Almost 34% of this agricultural waste energy comes from paddy straw, wheat accounts for 16%, and about 8% comes from maize. As for the supply of petroleum products, there was a supply of 26 million liters of gasoline, 95 million liters of diesel, and around0.7 million liters of kerosene. LPG imports amounted to 13,198 tons. Meanwhile, the total sales of electricity in the Sudurpashchim Province are 286 GWh. In the renewable energy sector, there are 6.3MW of micro-hydro plants installed in Sudurpashchim Province. Approximately 908 kWp of institutional Solar PV systems were installed, and 1,39,669 of SHSs were installed in the province. Most of the biogas plants are sized 4 cubic meters in the province. There are 51,179 domestic biogas plants with 2 large biogas plants, 87,326 mud ICSs, and 4,606 metallic ICSs in the province. In the Sudurpashchim Province, there is a potential of 7,722 MW, which comes to be 11% of the total national hydropower potential as per the WECS (WECS, 2019). NEA has developed and has projects under proposed plan totaling 240 MW in the Sudurpashchim Province and the IPPs have existing and planned in the range of 148 MW hydropower plants.

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

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

In the REF Scenario, the total energy demand is projected to undergo significant changes, starting at 37 PJ in 2022 and reaching 36 PJ in 2030. By the year 2050, this demand is anticipated to surge to 76 PJ, marking a twofold increase. Solid biomass will decline from 79% in 2022 to 54% of the total final energy in 2050. Petroleum products will jump to 30% of the total final energy in 2050 from 13% in 2022. This indicates that dependence on imported fossil fuels increases tremendously if proper policy decision is not undertaken in time to curtail consumption of fossil fuels and to focus on clean energy resources available in the country. Electricity demand attains 6% of the total final energy in 2050. The installed capacity of power plants will crease from 79MW in 2022 to 734 MW in 2050.

In the SED scenario with the various energy transition measures, the final energy demand reaches 62 PJ in 2050. Solid biomass will still occupy 35% of the total final energy in 2050, as solid biomass is considered carbon-neutral and forest resources are available even maintaining the national requirement of forests coverage. Expected demand for petroleum products will be at 21% of the total final energy in 2050. Electricity demand is expected to reach 36% of the total final energy demand in 2050. In this scenario, the installed capacity of power plants reaches 439 MW in 2030 and 2,918 MW by 2050 respectively. GHG emissions in the SED scenario will be 384 kg/capita in 2050, compared to 686 kg/capita – almost 50% decline from the REF scenario. Electricity intensity of GDP reaches 3,065 kWh/million NRs in 2050 in the SED scenario, whereas it will be 655 kWh/million NRS in the REF scenario. It indicates that electricity intensity in the economic development achieves 5-fold increase in the SED scenario.

Policy Recommendations

- **Energy generation Capacity Development**

  The study shows that the province, as of now, has enough capacity of electric generation plant. However, the demand is going to increase at a higher rate if sustainable energy development goals are to be achieved. The under construction and planned plant capacity are supportive, but in the long run, it might not be enough to cater for the electricity demand. Thus, the province should focus on more plant capacity development, with integration of utility scale variable renewable energy generation plants like Solar, MHPs etc.

  Actors: Ministry of Physical Infrastructure Development – Sudurpashchim Province, Province Policy and Planning Commission; Alternative Energy Promotion Center; Nepal Electricity Authority

- **Energy Infrastructure Development**

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

  Actors: Ministry of Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Ministry of Physical Infrastructure Development – Sudurpashchim Province, Province Policy, and Planning Commission – Sudurpashchim Province; Nepal Electricity Authority – Sudurpashchim Province

- **e-Cooking Promotion**

  Given that the province has very low penetration of electric cooking technology users, the province should promote the use of e-cooking wherever possible. In the short term, the commercial sectors can be motivated to adopt eCooking, while with expanded reach and capacity for technology, electricity and awareness, full-fledged electrification in cooking 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, 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 Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Province Policy and Planning Commission – Sudurpashchim Province; Alternative Energy Promotion Center; Nepal Electricity Authority – Sudurpashchim Province

- **Energy Demand Creation**

  In the province, energy consumption is lower compared to more economically developed provinces, presenting an opportunity for demand creation, particularly for electricity. Currently, there's excess electricity production in the nation in wet seasons, risking wastage if demand isn't 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 Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Province Policy and Planning Commission – Sudurpashchim Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center; Nepal Electricity Authority – Sudurpashchim Province

- **Energy Efficiency Regulations**

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

  Actors: Ministry of Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Province Policy and Planning Commission – Sudurpashchim 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 Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Ministry of Physical Infrastructure Development – Sudurpashchim Province; Province Policy and Planning Commission – Sudurpashchim Province

- **Renewable Energy Commercialization**

  The findings highlight a concerning trend of underutilization and inefficient utilization of renewable energy sources in Nepal, particularly in the case of biomass. Despite its abundance, biomass predominantly fuels traditional open stoves in the residential sector, contributing to health hazards, environmental degradation, and resource depletion. This represents a non-productive use of energy and underscores the urgent need for intervention. By transitioning to clean energy alternatives for cooking in residential areas, such as improved cookstoves or biogas systems, there exists a significant opportunity to commercialize the forest sector as an energy resource. 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 Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Province Policy and Planning Commission – Sudurpashchim Province; 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: Province Policy and Planning Commission – Sudurpashchim Province; Water and Energy Commission Secretariat; Alternative Energy Promotion Center

- **Dedicated Authority / Institutional Body to Look Over Energy Sector**

  Currently there is no specific institutional body dedicated to the Energy sector in the province. Thus, it is recommended that there should be such an institution or authoritative body or unit that looks over the matters related to the energy sector separately. The body/unit should have authority to formulate and implement plans/policies as well as be responsible to maintain the data and information as well as coordinate with other related governing bodies in the province in related matters.

- Actors: Office of Chief Minister and Council of Ministers – *Sudurpashchim Province*; Province Policy and Planning Commission – *Sudurpashchim Province*; Water and Energy Commission Secretariate

- **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 Industry, Tourism, Forest, and Environment – Sudurpashchim Province; Ministry of Physical Infrastructure Development – Sudurpashchim Province; Province Policy and Planning Commission – Sudurpashchim Province ; Alternative Energy Promotion Center*

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Sudurpashchim 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 second lowest among the seven provinces due to the low number of industries as well as lower commercial activities in compared to more economically developed provinces. This study also indicates that with the core focus on energy security, reliability, and sustainability, Sudurpashchim 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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