TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO.: M-376-MSREE-2021-2023

Energy Demand Modelling and Emission Forecasting for the Penetration of E-mobility in Sudurpaschim Province

By

SURAKSHA PAL

A THESIS

SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN RENEWABLE ENERGY ENGINEERING

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

LALITPUR, NEPAL

NOVEMBER 2023

COPYRIGHT

TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "Energy Demand Modelling and Emission Forecasting for the Penetration of E-mobility in Sudurpaschim Province" by Suraksha Pal in partial fulfilment of the requirements for the degree of Master of Science in Renewable Energy Engineering.

Supervisor, Associate Professor Dr Nawraj Bhattarai
Department of Mechanical and Aerospace Engineering
Pulchowk Campus

External Examiner, Dr Madhusudhan Adhikari
Senior Energy Expert

Assistant Professor Dr Sudip Bhattarai
Head of Department
Department of Mechanical and Aerospace Engineering
Pulchowk Campus

Tribhuvan University
Institute of Engineering
Department of Mechanical and Aerospace Engineering
Pulchowk Campus

28th November 2023

Date

ACKNOWLEDGEMENT

I would like to sincerely thank everyone who contributed significantly to the preparation of this thesis paper. My sincere thanks to my supervisor associate professor Dr Nawraj Bhattarai for his important advice, steadfast support, and enlightening criticism during this research trip. I also want to express my gratitude to my professor associate professor Dr Ajay Kumar Jha and associate professor Dr Hari Bahadur Darlami for their insightful comments and recommendations. I am grateful to TU-NPAR-079/80-ERG-05-"Projection of Energy Demand and Emission Reduction for the Sustainable Use of Electric Vehicles in Nepal" for the opportunity to conduct desk study and literature review regarding the project. Additionally, I am indebted to the officers of DoTM offices of Sudurpaschim province who generously volunteered their time to make the data available for this study.

I want to thank my friends and family for always being there for me and for their support and encouragement. My successes have been motivated by their unwavering faith in my abilities. This study work is a product of the combined efforts of everyone listed, and I sincerely appreciate their priceless contributions.

ABSTRACT

This thesis paper focuses on the development of future energy demand and emissions projections for the road transport sector in Sudurpaschim Province of Nepal, spanning from 2022 to 2050. This analysis utilizes the Long-range Energy Alternative Planning (LEAP) modeling framework and explores three distinct policy strategies: Business As Usual (BAU), Nationally Determined Contribution (NDC) Scenario and Long Term Strategy (LTS) Scenario.

In 2022, passenger travel demand stood at 3.89 billion passenger kilometers, but it is anticipated to surge to more than 11.77 billion passenger-kilometers by 2050. Similarly, freight transport demand is expected to grow from 1.84 billion ton-kilometers in 2022 to 3.25 billion ton-kilometers by 2050. To meet these escalating transportation demands, the total final energy consumption (TFES) must increase from 2.59 PJ to 7.34 PJ, primarily relying on imported fossil fuels, with an annual growth rate of 3.78% from 2022 to 2050 under a business-as-usual scenario. During this period, greenhouse gas (GHG) emissions are projected to rise from 111.7 thousand MT of CO2 equivalent to in 2022 to 258.8 thousand MT of CO2 equivalent by 2050, representing a 3.41% annual growth rate. However, under the Nationally Determined Contribution (NDC) scenario, the total final energy consumption (TFES) must increase from 2.59 PJ to 3.7 PJ, primarily relying on electricity as a major fuel, with an annual growth rate of 1.32% from 2022 to 2050. During this period, greenhouse gas (GHG) emissions are projected to decline from 111.7 thousand MT of CO2 in 2022 to 30.8 thousand MT of CO2 equivalent by 2050, representing a CAGR of 4.49%. In Long Term Strategy (LTS) scenario, the energy demand is projected to rise from 2.6 PJ in 2022 to 3.0 PJ in 2050 with a CAGR of 0.48% while in case of pollutants, net zero emission is forecasted at targeted by the policy itself.

When assessing the contrast between BAU with NDC and LTS scenarios, in 2025, energy demand reduced by 3.16%, 21.09%, 28.61%, 36.79%, 43.31%, and 49.00% in 2025, 2030, 2035, 2040, 2045, and 2050, respectively in case of NDC with respect to BAU. Similarly, the LTS scenario as compared to BAU indicated reductions of reductions of 6.99%, 19.11%, 31.78%, 44.95%, 58.56%, and 59.61% in 2025, 2030, 2035, 2040, and 2045, and 2050 respectively. When assessing the contrast between BAU with NDC and LTS scenarios, in 2025, emissions reduced by 4.9%, 32.8%, 49.3%, 65.81%, 77.9%, and 89.2% in 2025, 2030, 2035, 2040, 2045, and 2050 in case of NDC with respect larger reductions to BAU scenario. Similarly, the LTS scenario as compared to BAU indicated reductions of 13.0%, 34.8%, 56.5%, 78.3%, and 100% in 2025, 2030, 2035, 2040, and 2045, respectively.

Keywords: Energy demand, Emission forecasting, BAU scenario, NDC scenario, LTS scenario, GHG emissions, net zero, LEAP modeling

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

AD	:	Anno Domini
BAU	:	Business as Usual
CAGR	:	Compounded Annual Growth Rate
CO_2	:	Carbon dioxide
DOED	:	Department of Electricity Development
DOTM	:	Department of Transport Management
GGGI	:	Global Green Growth Institute
GHG	:	Green House Gas
GWh	:	Giga Watt Hour
IC	:	Internal Combustion
IEA	:	International Energy Agency
IAEA	:	International Atomic Energy Agency
IPP	:	Independent Power Producer
Kl	:	Kilo Liter
LTS	:	Long Term Strategy
MOEWRI	:	Ministry of Energy, Water Resources and Irrigation
MOF	:	Ministry of Finance
MOFE	:	Ministry of Forest and Environment
MW	:	Mega Watt
NASA	:	National Aeronautics and Space Administration
NDC	:	Nationally Determined Contribution
NEA	:	Nepal Electricity Authority
NOC	:	Nepal Oil Corporation
NPC	:	National Planning Commission
OEC	:	Observatory of Economic Complexities
PJ	:	Peta Joule
Ppm	:	Parts Per Million

SDG	:	Sustainable Development Goal
SNDC	:	Second Nationally Determined Contribution
UNFCCC	:	United Nations Framework Convention on Climate Change
USD	:	United States Dollar
VFTC	:	Vehicle Fitness testing Center
WECS	:	Water and Energy Commission Secretariat

CHAPTER ONE
INTRODUCTION

1.1 Background

Despite the growing consensus that societies' use of energy and emissions are influenced not only by efficient technology but also by the socio-cultural factors like their lifestyles and energy using patterns, the apparent significance of these elements for energy demand and quantitative modeling frameworks or even scenario analysis has been used rarely. Particularly, there haven't been many attempts to incorporate these observations into projections of future energy consumption.

The transport industry has become increasingly important in the context of the global energy market during the past few years. It accounted for about 27.8% of the world's total energy demand in 2016 (Rivera Gonzalez, 2020). The high levels of fossil fuel consumption in road transportation are a major reason to be concerned worldwide, but particularly in developing nations Nepal. The study of energy consumption in transportation sectors of prime concern because of the following factors:

- Localized emissions of harmful gases within cities that negatively impact the health of people and animals (Xiaojun Hu, 2010)
- Rising emissions of GHG that cause global warming, starting at 20 Gt CO2e (billion metric tons) in 1990 to 37 Gt CO2e in 2017, or an increase of 2.3% annually (Andrew I. Kay, 2014)
- The reduction non-renewable resource stocks due to their high consumption
- The limited energy production substitute resources for global consumption (BP Statistical , 2019)

On the other hand, air pollution was ranked the fourth leading risk factor for early death worldwide, following high blood pressure, tobacco use, and poor diet. It was reported to contribute to 6.67 million deaths in 2019 (State of Global Air, 2020) . As of 2022, the quantity of carbon dioxide in the atmosphere is at its highest peak, i.e., 412 parts per million, and it continues to rise. This figure indicates a 47 percent rise since the start of the Industrial Era when the concentration was close to 280 ppm (NASA, 2022). Transportation is one of the most fossil-fuel-dependent sectors and accounts for 37% of CO_2 emissions from end users (IEA, 2022). Road transport contributes to three-quarters of the total emission from the transportation sector. Passenger vehicles contribute to 45.1% while freight accounts for 29.4% of emissions (IEA, 2018).

Air pollution is one of the severe problems and the transportation industry is the predominant source of air pollution in the major cities of Nepal. With the expansion of road networks and the rapid increase in the number of substandard vehicles on congested roads, air quality has been steadily getting worse. Future Kathmandu Valley residents may experience a major problem with air pollution (Dhiraj, Venkatappa, & Adhikary, 2008). In the upcoming years, it is expected that transportation activity would increase significantly. In the absence of strict emission control measures, it is anticipated that pollutant emissions will also rise. (Ghimire & Shrestha, 2014). The intricate relationship between fuel properties, levels of combustion, interactions with other gases, and atmospheric conditions determines how much air pollution is produced by automobiles. The variability in emissions in different vehicles is due to the difference in vehicle/fuel characteristics, fleet characteristics, and operating characteristics (Sharma & Roychowdhury, 1996).

Nepal is a developing country dependent largely on traditional source of as its energy but the energy consumption in transportation sector is dominated by fossil fuel. The most common types of fuel used for road transportation are petrol, and diesel. Although these fuels differ greatly in how they are used and handled, for energy and GHG calculations, they all are more or less the same (Sharma & Shrestha, 2023).

A study shows that if vehicle fuel efficiency is increased by 30% by the year 2030, it will decrease overall fuel demand by 9%, CO_2 by 9%, and PM10 by 10% (Bajracharya & Bhattrai, 2016).

A study examined at the transportation sector's emissions, which would more than double between 2012 and 2050. The cumulative reduction in GHG emissions from 2013 to 2050 under the electric vehicle scenario is about 46 thousand metric tonnes CO2e (21.9%); for the electric mass transportation scenario, it is about 60 thousand metric tonnes (27.3%); and for the combined scenario, it is about 80 thousand metric tonnes (37%) (Dhital & Shakya, 2014).

Petrol is the most common liquid fuel for internal combustion engines. With no reserves of the fossil, Nepal is completely dependent on import of these and fuels. Reports show that Nepal imported refined petroleum worth USD 1.5 billion (OEC, 2021). The increasing trend of import of refined oils is shown in Figure 1.

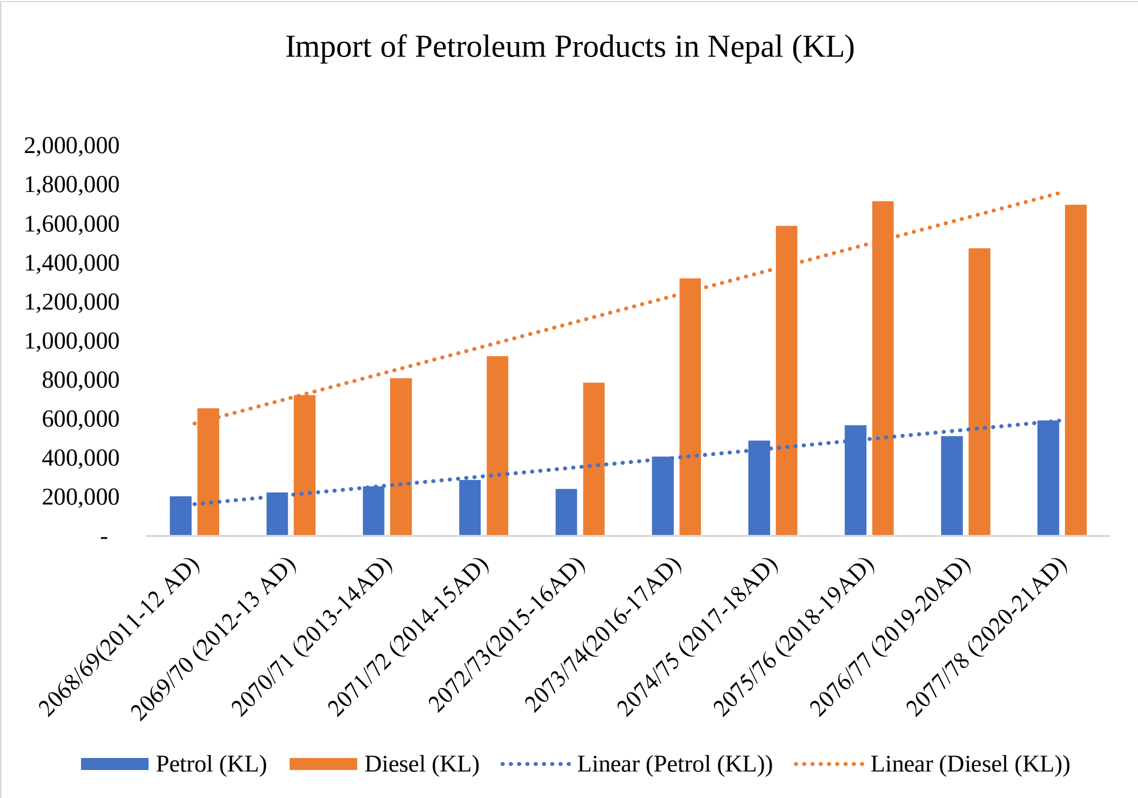


Figure 1 Graph showing the import of petroleum products in Nepal *(Nepal Oil Corporation, 2021)*

Nepal is a developing country dependent largely on traditional source of as its energy but the energy consumption in transportation sector is dominated by fossil fuel. The most common types of fuel used for road transportation are petrol, and diesel. Although these fuels differ greatly in how they are used and handled, for energy and GHG calculations, they all are more or less the same (Sharma & Shrestha, 2023).

With a hydropower potential of 83,000 MW, Nepal can utilize the locally available resources to replace the IC engine run transportation sector by electric vehicles. The replacement of vehicles can benefit Nepal in 3 major sectors.

- Environment by cutting down the GHG emissions
- Economy by decreasing the massive imports of refined petroleum products and increasing the total energy consumption from the internal production.
- Energy by the utilization

Further, Nepal has already developed the Second Nationally Determined Contribution (SNDC) for implementing Sustainable Development Goals (SDGs) and Long Term (LTS) Strategy for Net Zero Emission (NZE), which specifically targets to increase the share of electric vehicle to reduce GHG emission.

This study may develop the roadmap for the promotion of electric vehicles along with identification of barriers and their solutions in one of the provinces of Nepal. The roadmap for transitioning to the electric vehicle shall be developed based on the data related to the supply/import of petroleum fuels and its use in transportation sector. Based on the historical data regarding the supply/import of the petroleum product, the energy model shall be developed and accordingly the energy and fuel required shall be forecasted up to 2050 in five years interval based on several national policies and targets. The study shall further analyze the emission reduction due to transition towards the electric vehicles based on Government policies and plans. Based on the outcome of the study, a roadmap to transition to electric vehicle can be developed.

The challenges faced by Sudurpaschim Province in its transportation sector, compounded by its status as one of the least developed regions, underscore the urgent need for strategic interventions. By addressing the issues of heavy reliance on imported fossil fuels, developing a clear roadmap for integrating electricity generation into the transport sector, and bridging the gap in financial feasibility studies for electric vehicles (EVs), this study becomes instrumental. Furthermore, in the context of Sudurpaschim's unique challenges, the findings of this study can serve as a valuable database for informing sustainable and energy-efficient planning in the transportation sector, providing a crucial foundation for the province's future developmental initiatives.

The goal of the study was to shed light on potential avenues for energy consumption and environmental effects, providing useful data for developing sustainable energy plans and policies.

1.2 Problem Statement

The statement of problem is as follows:

- Sudurpaschim province heavily relies on imported fossil fuels for transportation, leading to vulnerabilities and contributing to greenhouse gas emissions
- The province's increasing electricity generation trend necessitates a roadmap for its integration into the transportation sector, crucial for addressing economic disparities
- While the government promotes electric vehicles, Sudurpaschim lacks comprehensive studies for the transportation sector's shift to e-mobility.

1.3 Objective

The objectives of the research are listed below:

1.3.1 General Objective

To develop a roadmap for achieving low greenhouse gas (GHG) emissions in the transportation sector of Sudurpaschim province.

1.3.2 Specific Objectives

- To assess the current energy demand and emissions in the transportation sector of the province
- To develop a transport-specific energy model for projecting energy demand up to 2050 at the interval of 5 years
- To forecast greenhouse gas emissions up to 2050 in different scenarios at 5-year intervals

1.4 Limitations

While a thorough study was conducted to derive valuable outputs, certain limitations emerged during the research process. These limitations encompass the following points:

- The study relies on national-level targets for demand projection, as there is a dearth of comprehensive studies conducted at the provincial level.
- Rail transport was not taken into account within the scope of the study, thus representing a limitation in the overall analysis of transportation modes.
- The study's focus is narrowed to the consideration of only three specific exhaust emissions: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This selective approach may limit the broader understanding of the environmental impact of the transportation sector.
- The study lacks key assumptions such as people's living standards and individuals' willingness for vehicle ownership, relying solely on historical trends in vehicle growth rate.

This study is constrained by the absence of crucial assumptions, including factors such as people's living standards and individuals' willingness for vehicle ownership, extending its reliance solely on historical trends in vehicle growth rate and the policy implications. This limitation may impact the comprehensiveness of the analysis, especially in forecasting outcomes up to the year 2050, as it overlooks some of the potential shifts in socio-economic dynamics over the coming decades.

CHAPTER TWO
LITERATURE REVIEW

2.1 Energy Situation in Nepal

Nepal is a landlocked country surrounded by China in the north and India in the south, east, and west. The total energy consumption of Nepal is low concerning other developing counties. The total energy consumption in the year 2022 is 626 PJ (WECS, 2022). Nepal has no petroleum and reserved coal, so the primary energy source is Biomass such as fuelwood. Firewood comprises of 60.38% of the total energy, which is the major energy demand, followed by petroleum products (16.89%). The remaining sources of energy consumption are coal (9.34%), electricity (4.21%), animal waste (2.87%), agricultural residue (3.00%), and renewable (2.4%). This shows that Nepal is still dependent on fuelwood as the primary energy source (WECS, 2022).

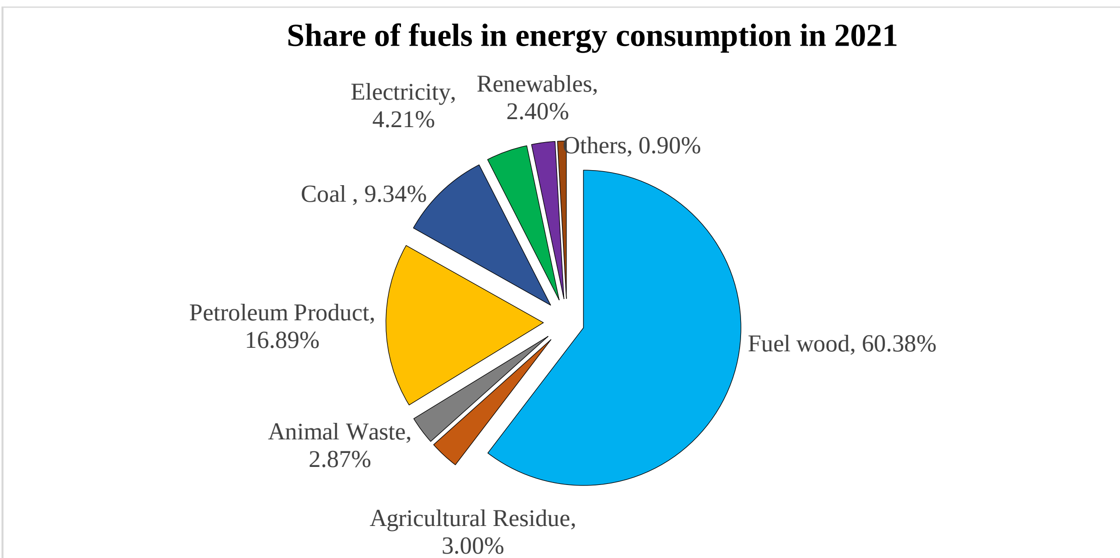


Figure 2 Share of fuels in energy consumption *(WECS, 2022)*

With the modernization of the country and the mechanization in the commercial and industrial sectors, the trend of energy consumption, especially in the commercial, industrial, and transport sectors is growing rapidly while the share of energy consumption in the residential sector is in a downward trend. In the fiscal year 2008/09, it had major share in the residential sector (89%) followed by transport (5.21%), industrial (3.34%), commercial (1.28%), and others (1.09%). However, as of 2021, the share of energy consumption for residential, industrial, commercial, transportation, and other sectors have varied and reached 63.2%, 18.3%, 7.0%, 9.0%, and 2.4%, respectively (WECS, 2022).

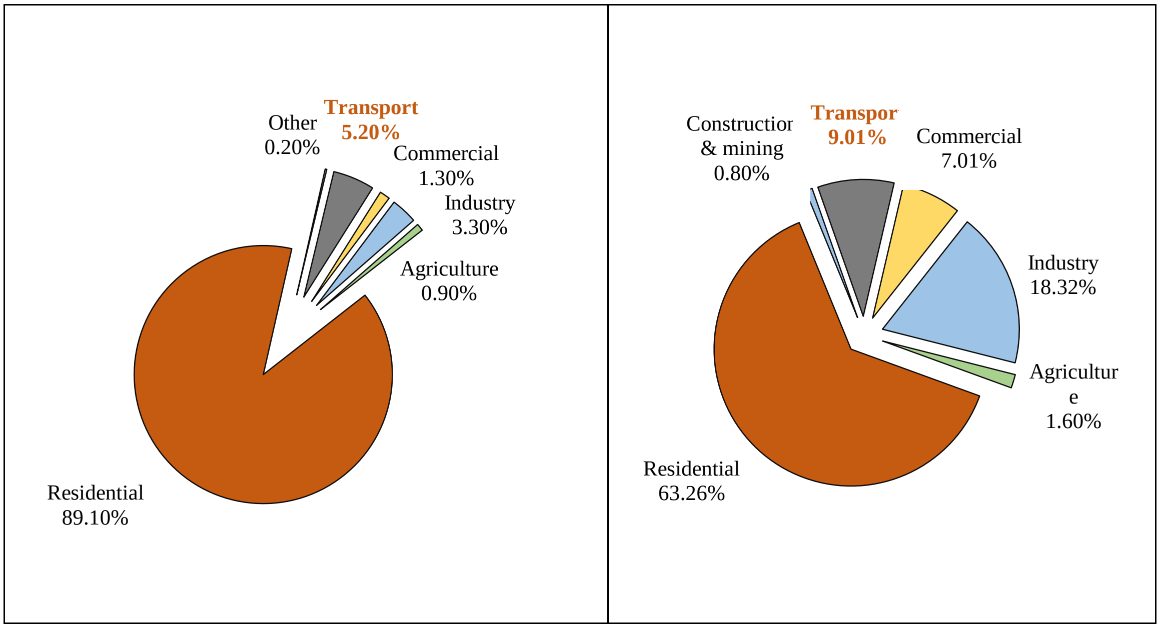


Figure 3 Sectoral Energy Consumption in 2010 (left) and 2022 (right) *(WECS, 2022)*

Glancing at the trend in the use of traditional, commercial, and renewable energy over the last three years, that is, from 2019 to 2021, consumption has increased at a rate of 1.57%, 6.19%, and 8.94%, respectively.

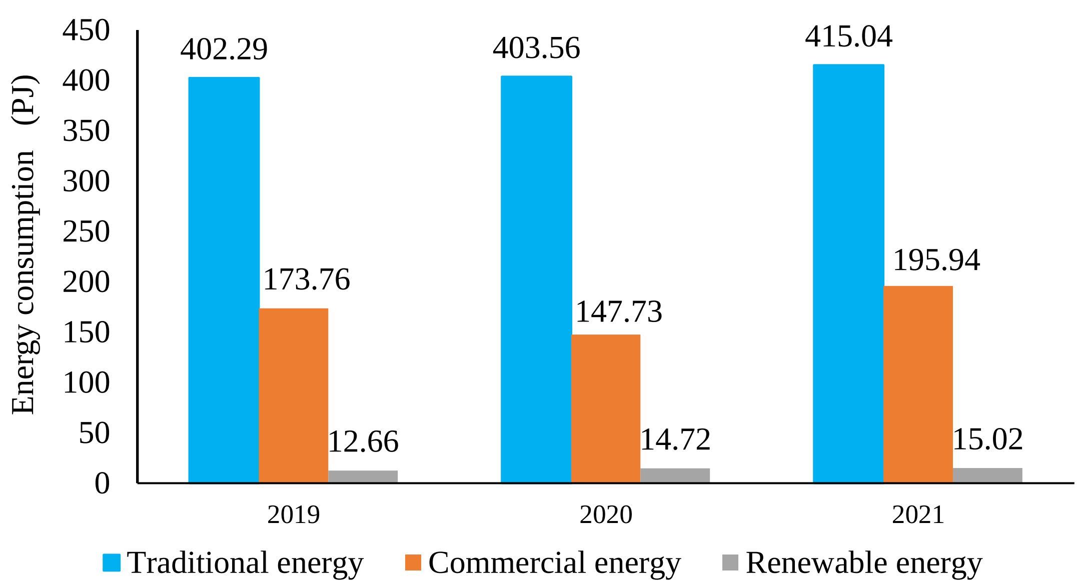


Figure 4 Energy consumption source *(WECS, 2022)*

Although there is a significant increase in the consumption of renewable and commercial energy, the dominant source used in Nepal is still traditional energy. Hence, to achieve sustainable development goals in energy, some drastic actions are required and possible only by proper energy planning.

The diesel consumption is high due to infrastructure development, heavy equipment, freight vehicles, and industrial uses. In 2015/16, imports was affected due to the border blockage issue. However, kerosene is in the phase-out stage, so it has decreased with an annual rate of 11.39%. The trend for the supply of petroleum products in Nepal is shown in Figure 5.

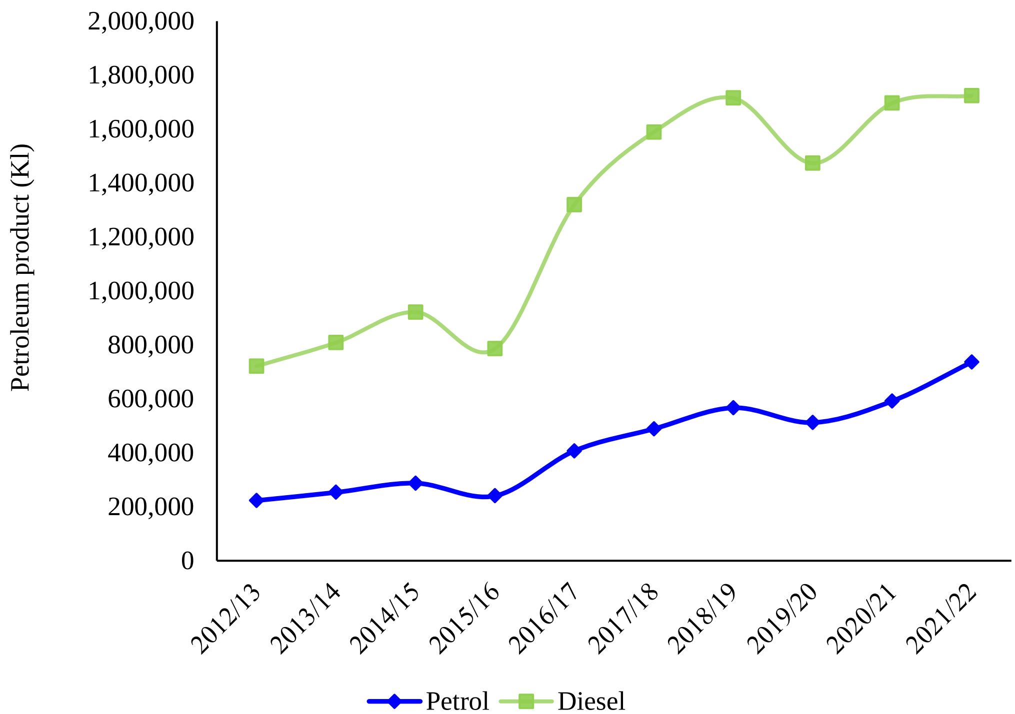


Figure 5 Supply of Petroleum Product (*(WECS, 2022)*

The total electricity available in the country is due to Nepal Electricity Authority (NEA) owned generation, Independent Power Producer (IPP), and import from India. Electricity generated by AEPC is included in NEA electricity. The electricity produced by different power producers is shown in Figure 6. The total available electricity in the year 2021 was 8,851 GWh while in the year 2022 was 11,064 GWh.

In the fiscal year 2010/11, the electricity produced by NEA, IPP, and imports from India was 2122 GWh, 591 GWh, and 639 GWh, respectively. The production has been increasing with an annual growth rate of 7.25%, reaching 3021 GWh, 2991 GWh, and 1729 GWh, respectively, in the fiscal year 2020/21. The share of imports from India has increased substantially more than NEA and IPP.

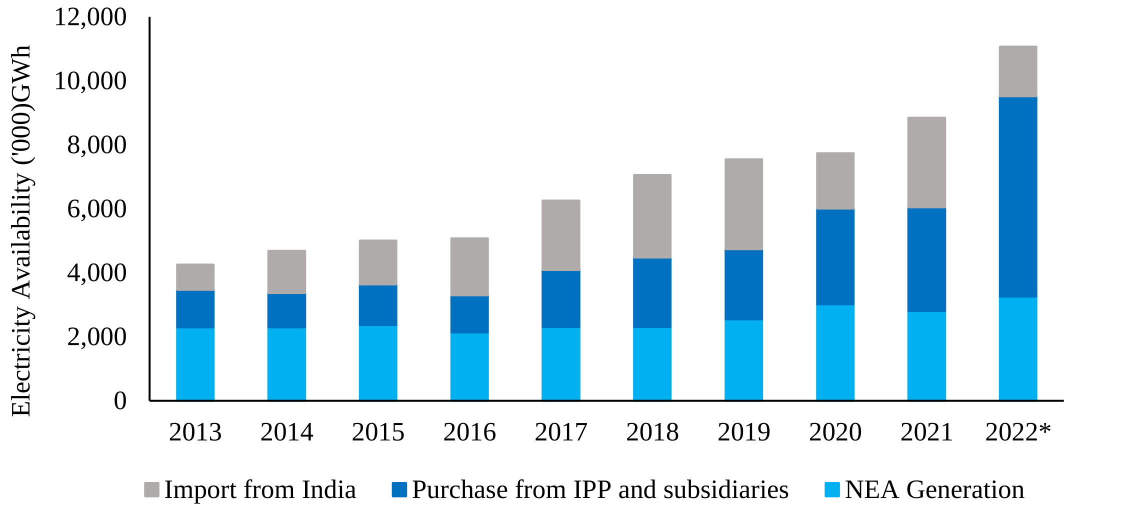


Figure 6 Availability of electricity in Nepal (*(WECS, 2022)*)

2.2 Emission Situation in Nepal

Energy use and consumption emit more GHGs worldwide than any other anthropogenic activities. Burning fossil fuels such as coal, oil, and natural gas converts the carbon in the fuel to CO_2, the predominant gas contributing to the greenhouse effect. The energy sector includes all fuel combustion-related emissions from energy industries, manufacturing and construction, transport, and other source categories. Energy efficiency improvement and fuel-switching from fossil fuels to electricity in transport, residential/domestic, commercial, and agriculture sectors offer deep de-carbonization to achieve a net-zero targets.

According to International Energy Agency, global energy-related CO_2 emissions in 2019 were 3.3 billion tonnes, of which 33% contribution was from advanced economies and the remaining from the rest of the world. In 2019, developed countries observed a decline in their CO_2 emission by 3.2% from the 2018 level, whereas there was still a 2% growth in emissions from the rest of the world during the same period (IEA, 2020).

Nepal's goal is to achieve net zero emissions from 2020-2030. However, the consumption of CO_2 emissions in 2019 is shown in the table below. The total GHG emission is 17.18 CO_{2eq} while the residential sector contributes the more emission, followed by the transport sector. The emission by the transport sector is 5.15 CO_2 equivalent which is around 30% of the emissions from the energy use. This shows that the emission by the transport sector is higher, so if the reduction in emission by the transportation is reduced, the overall emission can get reduced significantly.

Table 1 Emissions in 2019 (in a million Metric tonnes of carbon dioxide equivalent)

Sectors	Methane	Nitrous Oxide	Carbon dioxide	CO_2 equivalent
Residential	0.41	3.57	2.09	6.07
Transport	0.40	0.01	4.73	5.15
Industrial	0.02	0.02	4.45	4.49
Commercial	0.01	0.13	0.54	0.69
Agricultural	0.00	0.00	0.78	0.78
Total	**0.85**	**3.74**	**12.59**	**17.18**

(WECS, 2022)

2.3 Policy Review

A review of the major energy policies of the country was done. Some of those policies are mentioned below:

2.3.1 Sustainable Development Goals

The SDG7 targets include achieving, by 2030, (i) universal access to affordable, reliable and modern energy services, (ii) increasing substantially the share of renewable energy in the global energy mix and (iii) doubling the global rate of improvement in energy efficiency (NPC, 2017).

Ensuring access to affordable, reliable, and modern energy for all is a daunting task. However, given the immense hydro power potential, and with the private sector becoming more competent in power generation, grid connectivity expanding, and alternative modern energy sources being capitalized, the country can meet the targets. Thus, the proposed specific targets for SDG 7 include:

- Increase in proportion of population with access to electricity from 74% in 2015 to 90.7% in 2025 and 99% in 2030
- Increase in per capita electricity consumption from 80 kWh to 1027 kWh in 2025 and 1500 kWh in 2030
- Increase in renewable energy share in total final energy consumption from 11.9% in 2020 to 37.3% in 2025 and 50% in 2030
- Increase in installed capacity of hydropower from 782 MW to 10260 MW in 2025 and 15000 MW in 2030
- Increase in share of electric vehicle in public transport from 1% in 2020 to 35% in 2025 and 50% in 2050

2.3.2 Second Nationally Determined Contribution

Nepal's second NDC outlines actions to implement adaptation and mitigation actions to protect and improve the livelihoods of climate vulnerable communities and approaching towards Low CarbonEconomic Development. The Second NDC includes policy targets in each section that are well aligned with Government of Nepal's 15th five-year plan, relevant sectoral policies and strategies, climate change policy, and other national documents (Government of Nepal, 2020). The specific targets related to the transportation sectors are:

- In 2025, sales of electric vehicle will be 25% of all private passenger vehicle sales, comprising of two-wheeler and 20% of all four-wheeler public passenger vehicle sales excluding e-rickshaws and electric tempos. As a consequence, there will be decreased in fossil fuel energy demand from 40 PJ to 36 PJ. This target will mitigate 2,988 Gg CO_{2eq} to 2,734 Gg CO_{2eq}.
- By 2030, electric vehicles sales will increase to cover 90% of all private passenger (two wheelers and 60% of four-wheeler public passenger vehicle excluding e-rickshaw and e-tempos. Thus, mitigation of emission will be from 3,640 Gg CO_{2eq} to 2,619 Gg CO_{2eq}.
- By 2030, develop 200 km of electric rail network to use as public travelling as well as freight transportation.

2.3.3 Nepal's Long-term Strategy for Net-zero Emissions

Nepal's Long-term Strategy for Net-zero Emissions (LTS) has been prepared with the objective of developing Net-Zero emissions by 2050 in different economic sectors. It compares emission reduction in 2030 and 2050 with existing and added measures. According to LTS, 1.9 million Metric tonnes of CO_2 equivalent emission reduction can be achieved in 2030 and 8.2 million Metric tonnes of CO_2 equivalent reduction in 2050, i.e., 26% and 41% reduction in 2030 and 2050, respectively, compared to the reference scenario with existing measures and can be reduced to 97% by 2050 with additional measures. (UNFCCC, 2021). The strategic actions are mentioned below:

- Promotion of electric mass passenger transport.
- Switching fuel to clean energy (electricity, fuel cells, and synthetic fuels/biofuels in aviation).
- Electrification in freight transport.
- Installation and expansion of charging stations.

2.3.4 National Energy Efficiency Strategy

The National Energy Efficiency Strategy was developed by the Ministry of Energy, Water Resources and Irrigation and approved by the cabinet meeting of the Government of Nepal (GoN) in November 18, 2018 with the vision to assist in energy security by increasing the energy access through efficient use of available energy. This strategy was developed to promote energy efficiency by effectively implementing energy efficiency programs through establishing policy, legal and institutional frameworks. The goal of the strategy is to double the average improvement rate of energy efficiency in Nepal from 0.84% which existed during the period of 2000-2015 to 1.68% per year in 2030 (MOEWRI, 2019).

2.3.5 National Action Plan for Electric Mobility

To accelerate the implementation of Nationally Determined Contribution (NDC), Global Green Growth Institute (GGGI) in coordination with the Ministry of Forest and Environment and Ministry of Physical Infrastructure and Transportation has developed the National Action Plan for Electric Mobility in 2018 (GGGI, 2018). The overall goal of the

National Action Plan is to facilitate achievement of transport provisions laid out under the NDC. The specific objectives are:

- Undertake a comprehensive review of current gaps, barriers and challenges to the implementation and/or advancement of the NDC's transport provisions
- Identify and conceptualize clear and concrete action to support implementation of the transport provisions of the NDC
- Engage a comprehensive range of stakeholders, including public and private sectors and consumers, in participatory dialogue, prioritization and action planning for electric mobility
- Build the capacity of government partners, civil society and transport operators to support and advance the transport provisions of the NDC.

The action plan summarizes the policies and plans laid out by the Government of Nepal for the promotion of electric mobility in Nepal. The action plan further identifies the barrier for the e-mobility and has categorized them into four broader categories namely (a) Policy and governance; (b) Infrastructure and Markets, (c) Financing and resources and (d) Data and monitoring. The documents further suggest three priority action plan for overcoming these barriers namely (a) Unit for electric mobility, (b) National program for electric mobility and (c) National financing vehicle for electric mobility.

2.3.6 Assessment of Electric Mobility Targets for Nepal's 2020 NDC

The documents present analysis of national and international policy frameworks, markets, technologies, finance and electricity availability and through numerous expert and stakeholder consultations, to help inform Nepal's 2020 NDC targets on e-mobility (MoFE, 2021). Additionally, this assessment also helps inform NDC implementation by recognizing crucial gaps in Nepal's policy, markets, finance and energy sector and identifying solutions to meet them. The document further develops the model for energy and emission forecasting up to 2030 in the business as usual and ambitious scenarios by accounting the new vehicle sales. Compared to the BAU Scenario, the Ambitious E-Mobility Scenario decreases fossil fuel dependency from the transportation sector by around 9% in 2025 and 28% in 2030 similarly, the emission in the ambitious e-mobility scenario in transportation sector decreases by around 8% in 2025 and 28% in 2030.

2.3.7 Road, rail and transport development for prosperous Nepal – five-year strategic plan (2073-2078)

Prepared by Ministry of Physical Infrastructure and Transportation, the strategy focuses on the development and strengthening of the road network, expanding the rail network and making the transport management system effective. The strategy mentions that the government will formulate policies to promote public transport and walking, while discouraging the use of private vehicles, in order to secure safe, effective, pollution-free and accessible transport for all. While the strategy primarily focuses on expanding the road network, it has proposed the conversion of 20% of vehicles in Nepal to clean vehicles by the next five years (NPC, 2019).

2.3.8 Environment-friendly Vehicle and Transport Policy, 2014

- Development and extension of environment-friendly electric vehicles and transportation.
- Rules and regulations to allow conversion of technically feasible motor vehicles into electric vehicles.
- Aim to exceed 20% of vehicle fleets to be environment-friendly by 2020.
- Construction of safe cycle tracks and efficient charging stations for electric vehicles to reduce emissions.
- Tax reduction and the provision of low interest loans for private consumers to purchase environment-friendly vehicles (Clean Energy Nepal, 2014).

2.3.9 2021 United Nations Climate Change Conference -COP 26

In this policy, a roadmap for climate finance is provided and an increment in climate finance is provided to meet 'Nepal's needs (UNFCCC, 2021).

- Remain cumulatively net zero carbon from 2022-2045 and become carbon negative.
- Halt deforestation and increase forest cover to 45% by 2030.
- Ensure all vulnerable people are protected from climate change by 2030.

2.4 Transport Sector

Transport is the second sector that receives the most government money. However, the people living in Nepal are deprived of affordable transport services. Over the few years, the number of vehicles in the country has increased. The number of private vehicles, mostly the motorcycles, has increased dramatically. This increment in several vehicles has effect on the import of petroleum products such as petrol and diesel. The significant increase in motor vehicles also caused frequent fuel shortages as the Nepal government cannot pay for fuel imports.

Development of transportation sector plays a significant role in the economic growth of the country. For development of the transport sector, proper planning and policies should be developed to increase the accessibility and condition of private vehicles mark as it provides long-term sustainability and also the emissions by vehicles are reduced with the reduction in the number of vehicles. This environmental problem can also be reduced by replacing the transport sector with electric vehicles (EV). In the transport sector, the vehicle can be classified into two groups, i.e. passenger (intercity and intracity) and freight vehicle. Passenger vehicles consist of motorcycles, cars, jeeps, vans, buses, micro buses, minibuses, tempos, e-rickshaws, airways, and ropeways, whereas freight vehicles consist of lorries, trucks, mini trucks, tractors, cargo vans, ropeways, and airways. The total number of vehicles registered in Nepal till 2078/79 is 4,882,267 as shown in Table 2. This shows that motorcycles are registered in large numbers.

Table 2 Total number of vehicles registered in Nepal

Vehicle type	Number of vehicle registered till Falgun 2078/79	Remarks
Bus	60,864	Passenger vehicle
Truck	34,720	Freight vehicle
Crane/Dozer/Excavator/Truck	119,938	Freight vehicle
Car/Jeep/Van	308,109	Passenger vehicle
Pickup	85,352	Freight vehicle
Microbus	11,418	Passenger vehicle
Tempo	87,115	Passenger vehicle
Motorcycle	3,940,458	Passenger vehicle
Tractor/ Power tiller	180,210	Freight vehicle

E rickshaw	44,746	Passenger vehicle
Others	9,337	Freight vehicle
Total	4,882,267	

(MoF, 2022)

However, all the transports are not in operating condition, mainly due to old age or technical problems According to the study conducted by S Malla on 2014, the operating factor i.e. share of vehicles currently in operation for the passenger vehicles vary from 0.4 to 0.6 depending upon their types. The operating factor of the different vehicles are highlighted in Table 3.

Table 3 Operating factor of the different vehicles

Vehicle type	Operation factor	Remarks
Bus	0.31	For mini bus 0.45; for large bus 0.42
Car/Jeep/Van	0.8	For taxi 0.5; for others 0.5
Microbus	0.55	
Tempo	0.58	
Motorcycle	0.7	

(Dhital & Shakya, 2014)

2.5 Energy Modelling Tools

For modeling future demand, different modeling tools can be used. Some of the modeling tools are LEAP (Low Emissions Analysis Platform), MAED (Model for Analysis of Energy Demand), TIMES (The Integrated MARKAL-EFOM1 System) etc. The modeling database is generated for a base year. This includes energy consumption, supply and resource assessment, and forecasted future energy demand.

2.5.1 Model for Analysis of Energy Demand (MAED)

MAED is one of the energy modeling tools developed by the IAEA (International Atomic Energy Agency). The MAED model evaluated future energy demand based on medium to long-term scenarios for socioeconomic, technological, and demographic developments. The starting point for using the MAED model is the construction of base year energy consumption. This requires compiling and reconciling necessary data from different sources, deriving and calculating various input parameters, and adjusting them. Then in the next step, the future scenario is developed by viewing the country's situation and objectives.

The model focuses exclusively on energy demand and even more specifically on demand for specified energy services. The various energy forms, i.e., electricity, fossil fuels, and renewable energy, would compete for a given end-use category of energy demand. This demand is specifically calculated in useful energy terms and then converted into final energy, taking into account the market penetration rates and the efficiency of each alternative energy source, both specified as scenario parameters. Non-substitutable energy uses, such as motor fuels for cars, and electricity for specific uses (electrolysis, lighting etc.), are calculated directly in terms of final energy.

2.5.2 Low Emission Analysis Platform (LEAP)

LEAP is a transparent and user-friendly tool for energy and climate mitigation planning that many organizations have adopted. It is distributed and supported by Stockholm Environment Institute (SEI) through the LEAP website. It is a powerful, versatile software for integrated energy planning and climate change mitigation assessment. It also calculates the benefits after the reduction in emissions.

LEAP is an integrated, scenario-based modeling tool that can track energy consumption, production, and resource extraction in all sectors of an economy. It is a medium to long-term modeling tool. LEAP supports a wide range of modeling methodologies: on the demand side, these range from bottom-up, end-use accounting techniques to top-down macroeconomic modeling. Most of its calculations occur on annual time steps, which can extend for an unlimited number of years.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Design and Framework

Research methodology is a specific techniques to identify, select, process and analyze information about the research problem. It illustrates the process and methods applied for the study of the selected topic. It consists of all the sequential steps adopted by the researcher in studying the subject matter.

3.1.1 Literature Review and Desk Study

A literature review is an overview of the available research for a specific scientific topic. Literature reviews summarize existing research to answer a review question, provide the context for new research, or identify important gaps in the existing body of literature (Hempel, 2020). It is the first phase in the research methodology. It will be conducted with the help of different books, academic reports from campus library and scholarly articles.

Literature review and desk study wan the starting point and the baseline to gather information and knowledge regarding the situation, regulations, plan and policies etc. regarding the existing status of road vehicles used in Nepal, Kathmandu Valley and Sudurpaschim province along with various goals and targets of the government. The main tasks carried out during this phase of work were:

- Literature review regarding the energy consumption in Sudurpaschim Province along with emission due to these vehicles
- Review of related plans, policies, regulations and guidelines related to net zero emission, shifting to clean energy etc. like SDG 7, SNDC, LTS, 15th Periodic plan etc.
- Review of various energy modelling tools along with their SWOT analysis. The energy modelling tools may be MAED-2, LEAP etc.
- Collected and analyzed the information relevant for the study from different authentic sources, institutions and authorities.

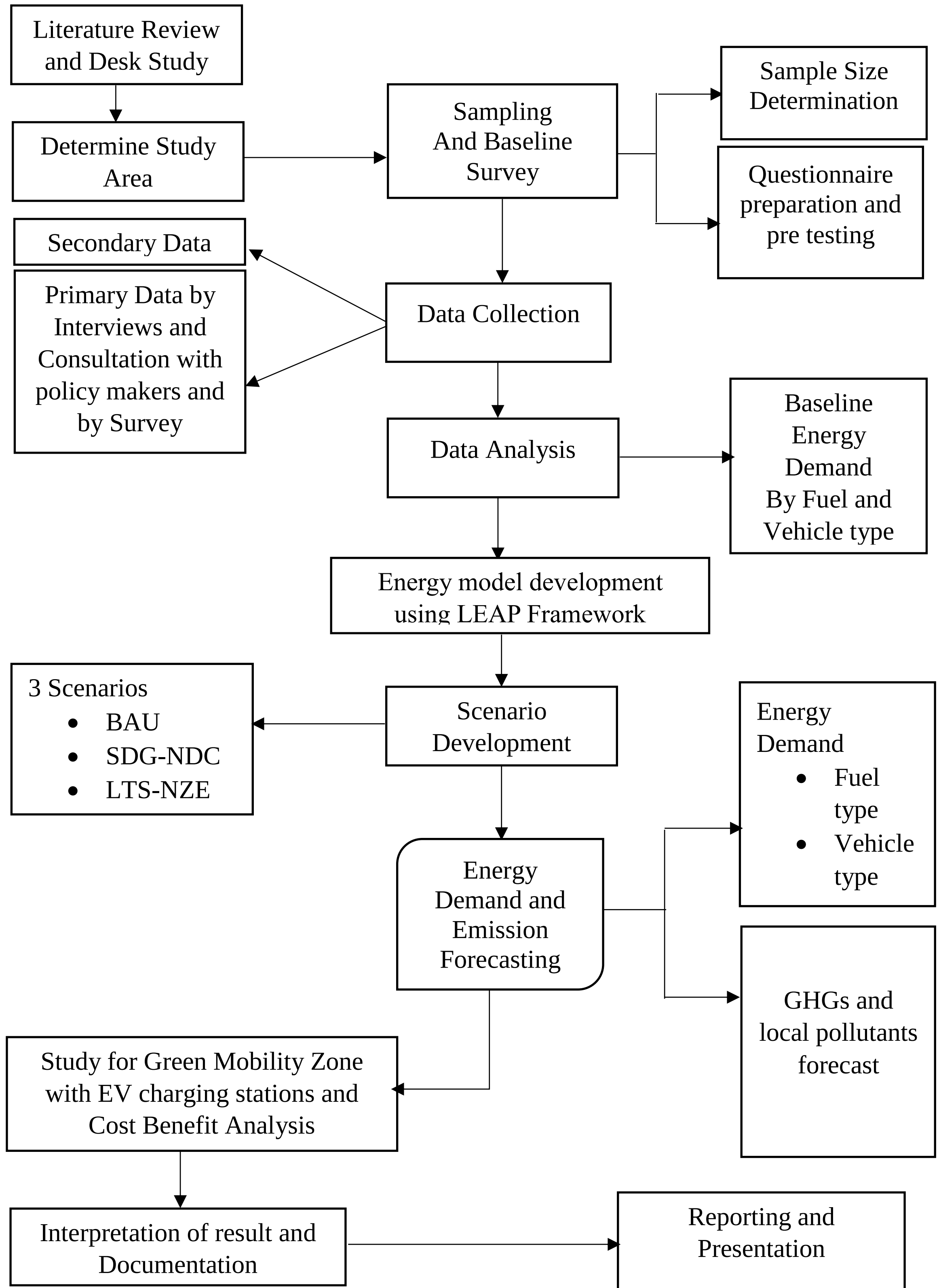


Figure 7 Study Design

3.1.2 Determination of Study Area

Sudurpaschim Province is a geographical and administrative region located in the far-western part of Nepal. It is one of the seven provinces of Nepal, which were created as a result of the country's transition from a unitary to a federal system of government. Sudurpaschim Province is known for its diverse ethnic and cultural makeup, as well as its varied topography ranging from the lowlands of the Terai region to the high mountains of the Himalayas. The province is bordered by Tibet (China) to the north and the Indian states of Uttarakhand and Uttar Pradesh to the west and south.

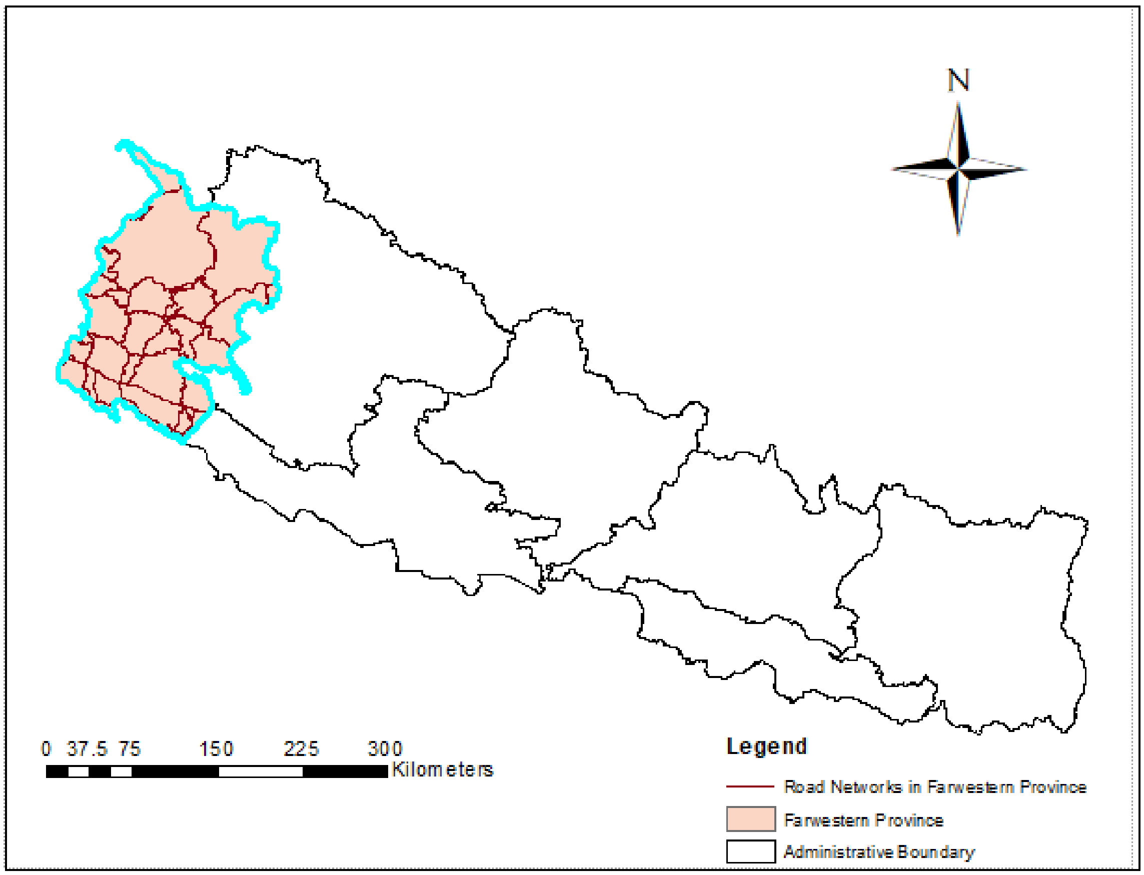


Figure 8 Map of Nepal showing Sudurpaschim Province

Sudurpaschim Province is further divided into multiple districts, each with its own unique characteristics and attributes. The province's administrative capital is Dhangadhi, while its largest city is Kailali.The research aimed to conduct a comprehensive study on energy demand modeling and emission forecasting in the transportation sector of Sudurpaschim

Province, Nepal. The region was selected as the study site due to its unique socio-economic, geographical, and transportation characteristics, which made it an ideal representative for examining energy consumption patterns and environmental impacts within the context of Nepal's sustainable development goals.

3.1.3 Sampling Survey

3.1.3.1 Sample Design and Sample Size Determination

Sample Design is a process of choosing a portion of population from a wider population in a research project is known as sample design. In order to provide a representative sample and produce accurate and generalizable results in survey research, the population size, desired confidence level, and margin of error were taken into account.

The sample size was be determined by using Krejcie and Morgan Formula.

$$n = \frac{x^2 * N * p * (1-p)}{e^2 * (N-1) + x^2 * p * (1-p)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(1)}$$

Here,

χ^2=χ square for specific confidence level (95%) = 3.841.

p = probability of success = 0.5

q= 1-p = probability of unsuccessful= 0.5

e = margin of error

N = Population size

n = required sample size

n_r: Total non-response rate = 5%,

Hence, total sample size = n+5% of n_r

3.1.3.2. Questionnaire preparation and pre testing

A detailed questionnaire was prepared for conducting the in transportation sector as shown in ANNEX II. The questionnaire includes various aspects as stated below:

- Socioeconomic information of the users
- Details of transportation registration
- Technical parameters like mileage, distance covered per day, fuel consumed per day, load carried etc.

- Barriers and hindrance for shifting to electric vehicles and preferred mode of electric vehicle etc.

Data was collected from Sudurpaschim province of Nepal. The data was used to calculate the average load factor, modal split and passenger km across the province in freight transportation, intercity transportation and intercity transportation. These factors were essential in determining the baseline scenario of energy consumption and the development of other scenarios of high economic growth, low economic growth and business as usual.

3.1.4 Data Collection

Data collection methods are techniques and procedures useful for gathering information for research. These methods include simple self-reported surveys to complex experiments and quantitative or qualitative approaches to data gathering. The common data collection methods included surveys, interviews, observations, focus groups, experiments, and secondary data analysis. The data collected through these methods were analyzed to draw conclusions about the study's research gap.

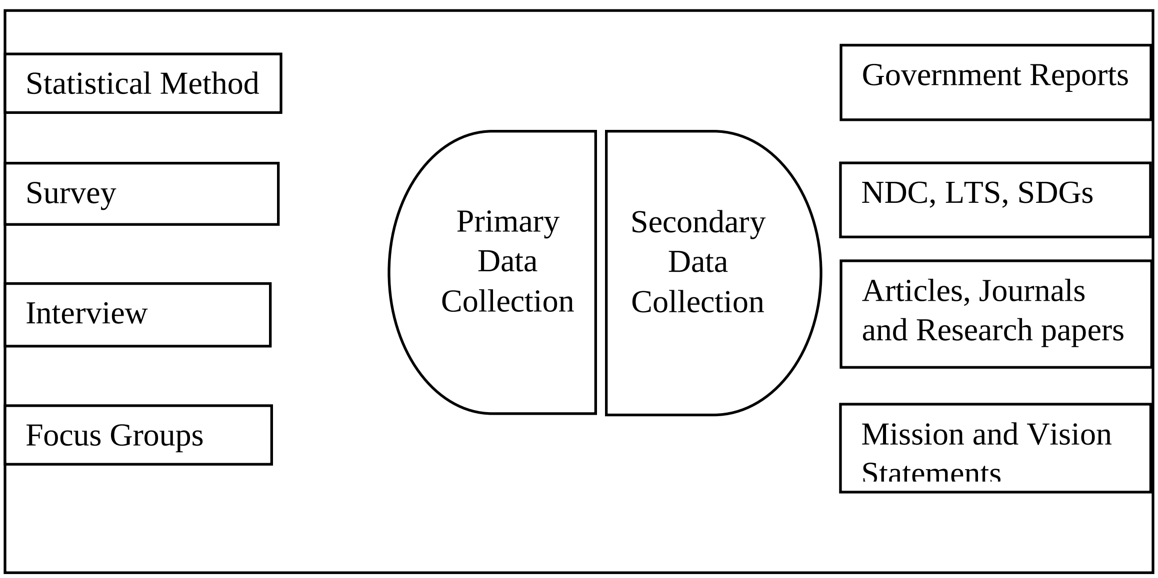


Figure 9 Data collection method used in the research process

The research required the collection of data associated with fuel import and supplies, number of vehicles, electricity sales, and fuel consumption by vehicle types, operating factor, occupancy etc. The information regarding the fuel import and supply was collected from Nepal Oil Corporation (NOC), the Department of Customs, the Water and Energy Commission Secretariat (WECS) etc. While data related to the number of vehicles by type, occupancy factor, load factor etc., was collected from the Department of Transportation Management (DoTM). Similarly, demographic data was be collected from the Central Bureau of Statistics (CBS).

In addition the data related to mileage, occupancy, distance travelled etc. was collected with the interviews with the sampled users operating these vehicles. Various information were also be collected from different reports and journals published by various nationally and internationally recognized organizations. Further the primary data regarding the demand of the fuel was collected by the questionnaires interview with the users and stakeholders in Sudurpaschim provinces of Nepal.

3.1.4.1 Primary Data

Primary data source is an original data source, from which the data are collected by the researcher for a specific research. During the study a questionnaire based interview was conducted with the owners of the vehicles to determine the fuel consumption, mileage, operating days in a year. The questionnaire is shown in ANNEX II. The data collected was further validated based on the secondary reports.

3.1.4.2 Secondary data

The process of gathering secondary data involves obtaining information from sources other than the primary user. This means that the data is pre-existing and has already been analyzed by someone else. For this research, secondary data was taken from various sources, such as newspapers, books, journals, government publications, economic survey reports, energy survey reports, and statistical documents, among others.

3.2 Baseline Energy Situation Development

The collected data was analyzed in excel using various conversion factors and calorific values to determine the energy consumption in passenger transport in the base year. In addition, the information regarding the efficiency of the IC engine vehicle was compared with the efficiency of the electric vehicle, and hence specific final energy and useful energy required for the movement of a vehicle shall be evaluated.

The energy model like Model for Analysis of Energy Demand (MAED), and Low Emission Analysis Platform (LEAP) were used to develop the energy model based on energy intensities. The energy model required detailed information about demography, economy, energy-consuming technologies (e.g., number of tractors, vehicles on the road, etc.), and energy consumption in various sectors according to end-use technologies, based on which different scenarios of future energy requirements are developed. All information was used for a base base-year, which was used as the reference year for projecting the future energy system's evolution. Similarly, the emissions from passenger transport was evaluated using International Panel on Climate Change (IPCC) guideline.

$$Annual\ Energy\ Consumption\ of\ Vehicles, E_x = Quantity\ of\ fuel\ per\ month * calorific\ value * number\ of\ operating\ days \ldots\ldots(2)$$

$$Specific\ energy\ consumptio = \frac{1}{n}\sum(E_x), where\ x\ denotes\ different\ samples \ldots\ldots(3)$$

$$Total\ energy\ consumption\ of\ vehicles\ types = \sum Specific\ energy\ consumption * total\ no.of\ vehicles \ldots\ldots(4)$$

(Dhital & Shakya, 2014)

3.3 Energy Model Development

Energy demand projection and scenario development is the basic prerequisite for formulating integrated energy policy, preparing the plan, and defining the activities for implementation. The future of energy demand depends on how the country's economy evolves in the coming years. Thus, three different scenarios were developed considering various growth rates. Business as usual scenarios, Sustainable Development Scenario, and Net Zero Emission scenario were developed considering various goals and targets of the government like SDG-7, SDG-13, NDC, COP-27, LTS, NZE etc. In addition, a policy intervention scenario to achieve net-zero emissions by 2050 was developed. The energy was forecasted based on the GDP growth rate, population growth rate and other varying parameters.

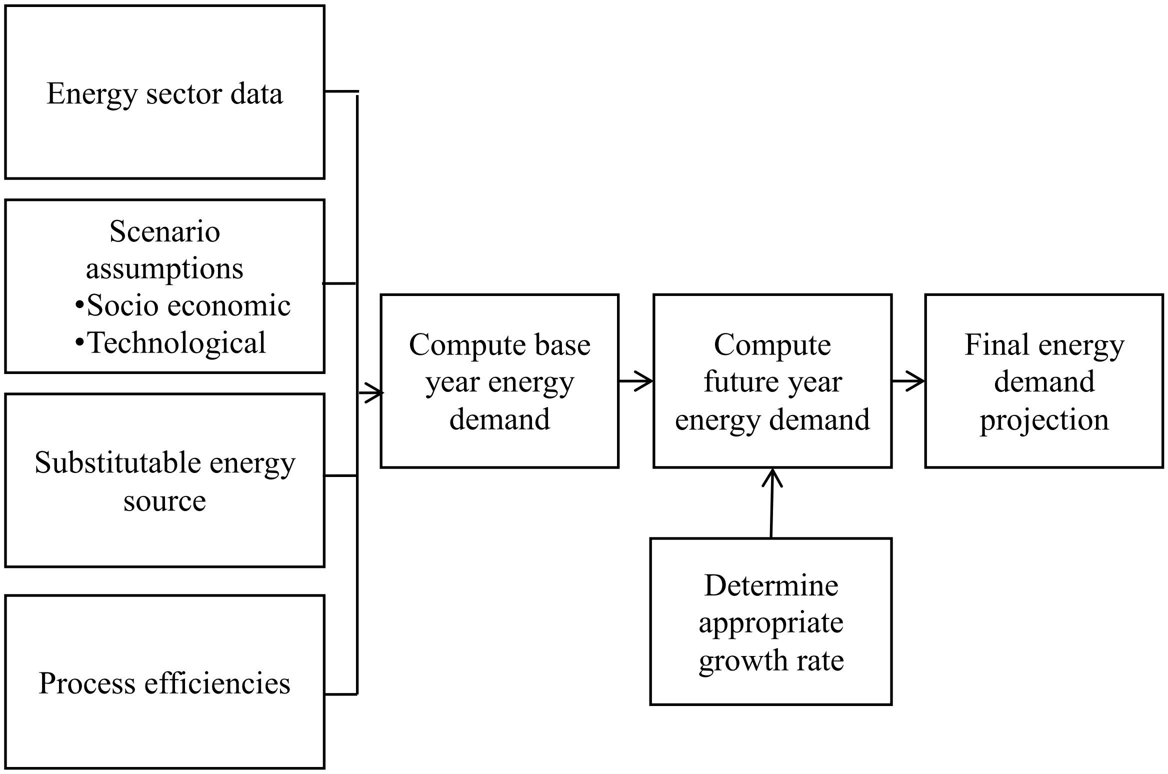


Figure 10 Energy Modelling Procedure by MAED

Long-range Energy Alternatives Planning (LEAP) is a software tool designed for energy planning and policy analysis. LEAP was first developed in the early 1990s by the Stockholm Environment Institute (SEI) and the International Institute for Applied Systems Analysis (IIASA) and has since been continually updated and improved. It provides an integrated platform for developing and analyzing energy systems, including the production, distribution, and consumption of energy. LEAP enables decision-makers to create detailed models of energy systems at the national, regional, or local level and to develop scenarios that project energy demand and supply over a long-term horizon, typically several decades. These scenarios can then be used to assess the environmental, economic, and social impacts of different energy policies and investment strategies.

The LEAP framework is highly flexible and customizable, allowing users to create models that are tailored to their specific needs. LEAP has been used to develop scenarios that project energy demand and supply over a long-term horizon, typically several decades. These scenarios can then be used to assess the environmental, economic, and social impacts of different energy policies and investment strategies. The software also includes a comprehensive database of energy-related data that can be used to populate models and develop scenarios.

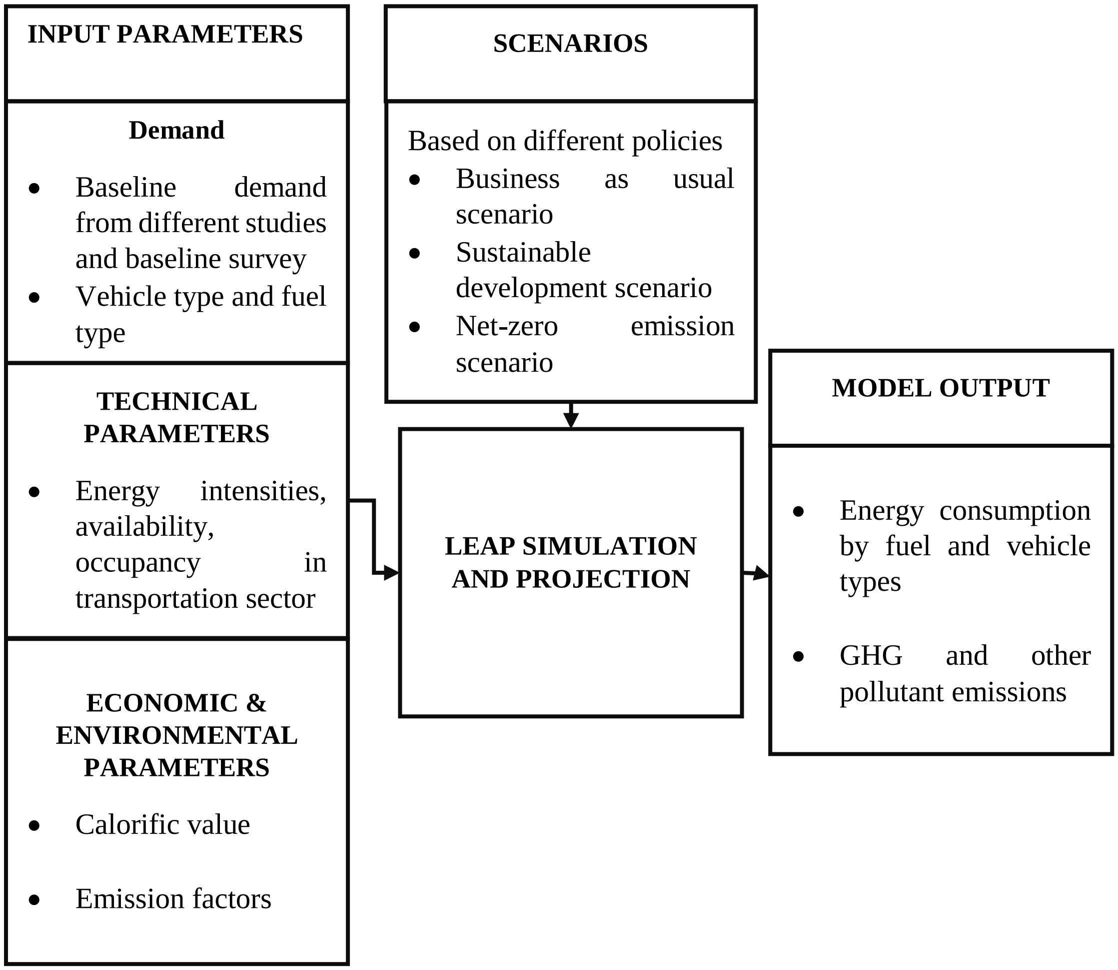


Figure 11 LEAP Framework Modelling

3.4 Energy Demand Forecasting

Energy service demand is the one of the essentials for forecasting the energy consumption as well as emission. In the study, passenger km (for passenger vehicles) and tons km (for freight vehicles) have been taken as energy service demands. The service demand was calculated using the formula:

$$\text{Service demand of nth year} = \text{service demand of base year} \times \left(\frac{\text{GVA of nth year}}{\text{GVA of base year}}\right)^{\alpha 1} \times \left(\frac{\text{Population of nth year}}{\text{Population of base year}}\right)^{\alpha 2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

(Shrestha & Rajbhandari, 2010)

Where,

α1 is elasticity for GVA and α2 is elasticity for population

In case of freight transport, population is not taken into consideration and service demand is calculated using GVA only. The elasticity of population for passenger vehicles was taken as 1.44 and for freight vehicles was taken as 0. The elasticity of GVA for passenger vehicles was taken as 0.41 and for freight vehicles was taken as 0.6 (Shrestha & Rajbhandari, 2010). The service demand up to 2050 was calculated and modelled in the LEAP framework.

The population growth rate considered in this study is based on the current population growth rate of the province and follows the similar pattern of projected growth rates as published by the United Nation Department of Economic and Social Affairs (UNDESA). Similarly, the growth in gross value added (GVA) for different scenarios have been considered based on several national studies of Nepal such as the Long-term strategy for Net Zero Emissions, Sustainable Development Goals, 15th Periodic Plan, and Energy Sector Vision 2050 etc.

Table 4 Population growth rate and Gross value added growth rate in the time frame of projection

Population Growth rate	2021-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
	0.06%	0.54%	0.51%	0.50%	0.49%	0.47%
GVA	2021-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
	4.1%	5.9%	4.4%	3.6%	3.0%	2.6%

These growth rates in population and GVA were calculated based on historical trends.

Sudurpaschim Province's population was projected from 2022 to 2050 based on five decades of historical trends. This approach aimed to provide insights into both future estimates and the historical evolution of demographic patterns in the region. The growth rates of population for different time intervals were calculated using trends taken from historical data as shown in Figure 12.

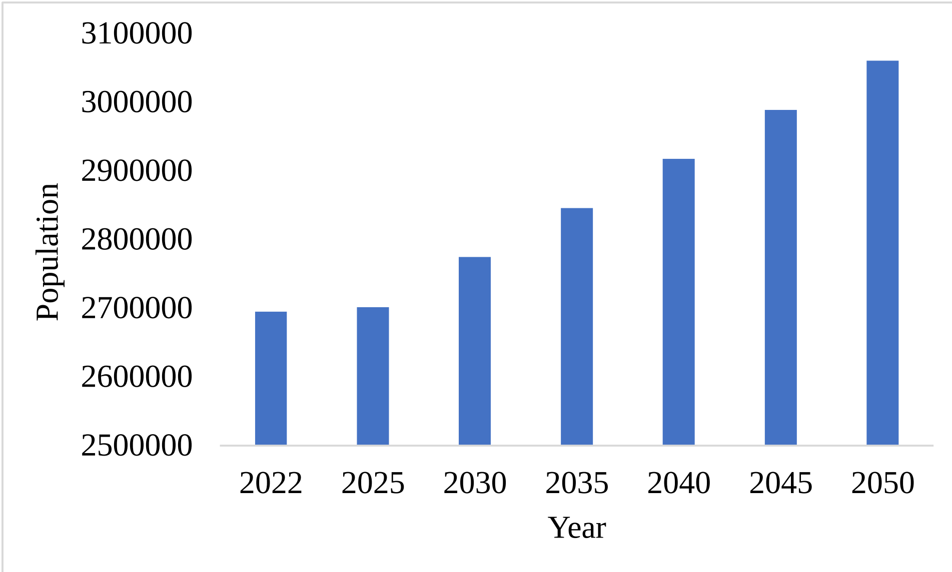


Figure 12 Projected population from 2022 to 2025

Similarly, GVA projections up to 2050 were based on historical trends, utilizing provincial data specifically for the transportation sector as shown in Figure 13.

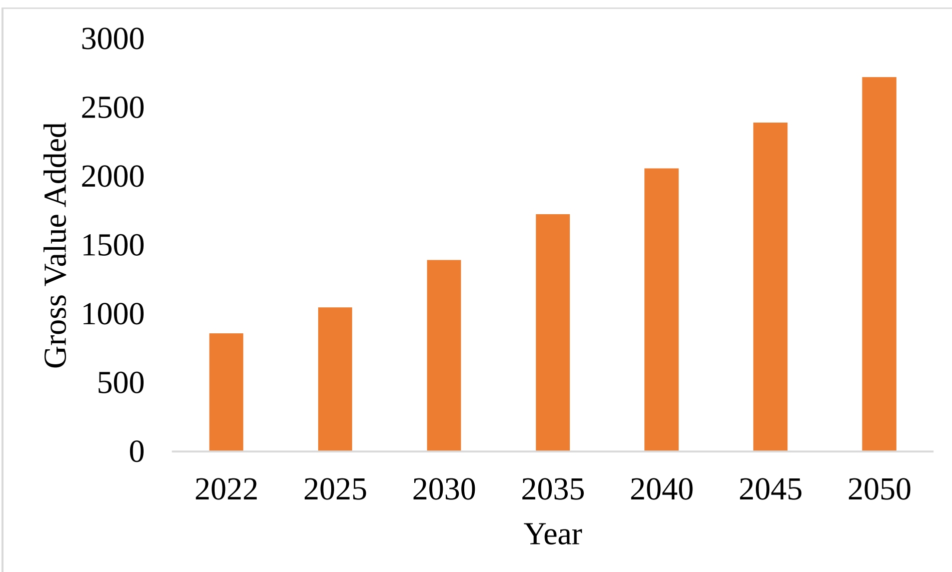


Figure 13 Projected GVA from 2022 to 2025

In the context of Sudurpaschim Province, the projections for population development, GDP growth, and energy intensity were integrated to forecast the future development pathways for the region's final energy demand. The energy intensities of different fuels were taken as follows:

a. For Petrol (Energy intensity in Mega joule per passenger kilometer)

- Two wheeler=1.21
- Car = 1.41
- Jeep =2.11
- Auto rickshaw=0.15

b. For Diesel (Energy intensity in Mega joule per passenger kilometer)

- Car =1.51
- Jeep =1.25
- Bus= 0.37
- Auto rickshaw=0.18
- Truck=0.37
- Tractor=0.37

c. For Electricity (Energy intensity in Mega joule per passenger kilometer)

- Car =0.32
- Jeep =0.59
- Bus= 0.17
- E rickshaw= 0.14
- Truck=0.49
- Tractor=0.49

From 2030, hydrogen is considered to be used as fuel in freight vehicles whose energy intensity is taken as 0.29 MJ/ passenger kilometer (Teske, Niklas, & Miyake, 2023).

Similarly, emission factors were considered for calculating the emissions from different fuels and vehicles. For petrol, 3180 gram of carbon dioxide per kilogram unit of energy consumed was considered to be produced. For diesel, 3140 gram of carbon dioxide per kilogram unit of energy consumed was considered to be produced. Similarly, for petrol, 1.7 gram of methane per kilogram unit of energy consumed was considered to be produced. For diesel, 0.17 gram of methane per kilogram unit of energy consumed was considered to be produced. For petrol, 0.14 gram of nitrous oxide per kilogram unit of energy consumed was considered to be produced. For diesel, 0.17 gram of nitrous oxide per kilogram unit of energy consumed was considered to be produced (United Nation Environment Programme, 2013).

3.5 Scenario Development

Scenario development serves as the fundamental requirement for formulating an integrated energy policy, establishing plans, and defining implementation activities. It involves scenario-based planning, a technique introduced in 1970, which aids in projecting and forecasting energy usage across various economic sectors. Although scenario-based projections do not provide exact energy usage patterns, they offer approximations that assist policymakers and planners in developing sustainable and low-emission development plans and policies.

(i) Business as Usual Scenario:

In business as usual scenario, it assumed that the growth will take place as the historical trends it has been following in the past years.

(ii) Nationally Determined Contribution Scenario:

The sustainable development scenario has been developed based on the targets of the NDC of Nepal. The major consideration in this scenario are:

- Sales of private passenger electric vehicles (including two-wheelers) in 2025 to be 25% of the total sales
- Sales of public passenger electric vehicles (excluding e-rickshaws and electric tempos) in 2025 will be 20% of total sales
- Sales of private passenger electric vehicles (including two-wheelers) in 2030 will be 90% of the total sales
- Sales of public passenger electric vehicles (excluding e-rickshaws and electric tempos) in 2030 will be 60% of total sales
- There is no change in the energy consumption pattern of freight vehicles

(iii) Long Term Strategy Scenario

The net-zero emission scenario has been developed based on the targets of the Long-term Strategy for net-zero emission. The major considerations within this scenario are:

- The passenger vehicles will completely shift to electricity by 2045
- The freight vehicles will completely shift to electricity by 2045

The energy projection was done using LEAP (Low Emission Analysis Platform) model. The base year considered in this study for energy demand analysis is 2022 and the energy was forecasted up to 2050 at the interval of 5 years. For the base year, the energy model was developed based on the data collected and analyzed.

3.5 Documentation and Reporting

The findings of the research study will be documented systematically and will be submitted to the department as the thesis report as per the requirement of the Department of Mechanical and Aerospace Engineering, Pulchowk Campus.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Study Area: Sudurpaschim Province

Sudurpaschim Province in Nepal was chosen as the study site due to limited existing research and the absence of sector-specific studies on energy demand and emissions in the transportation sector. This decision aimed to fill crucial knowledge gaps and address a lack of comprehensive data. The province's socio-economic diversity, unique geography, and the potential to inform sustainable development policies underscored its significance. By selecting an underrepresented region, the study aimed to provide valuable insights for informed decision-making and effective policy formulation in the context of transportation energy consumption and emissions.

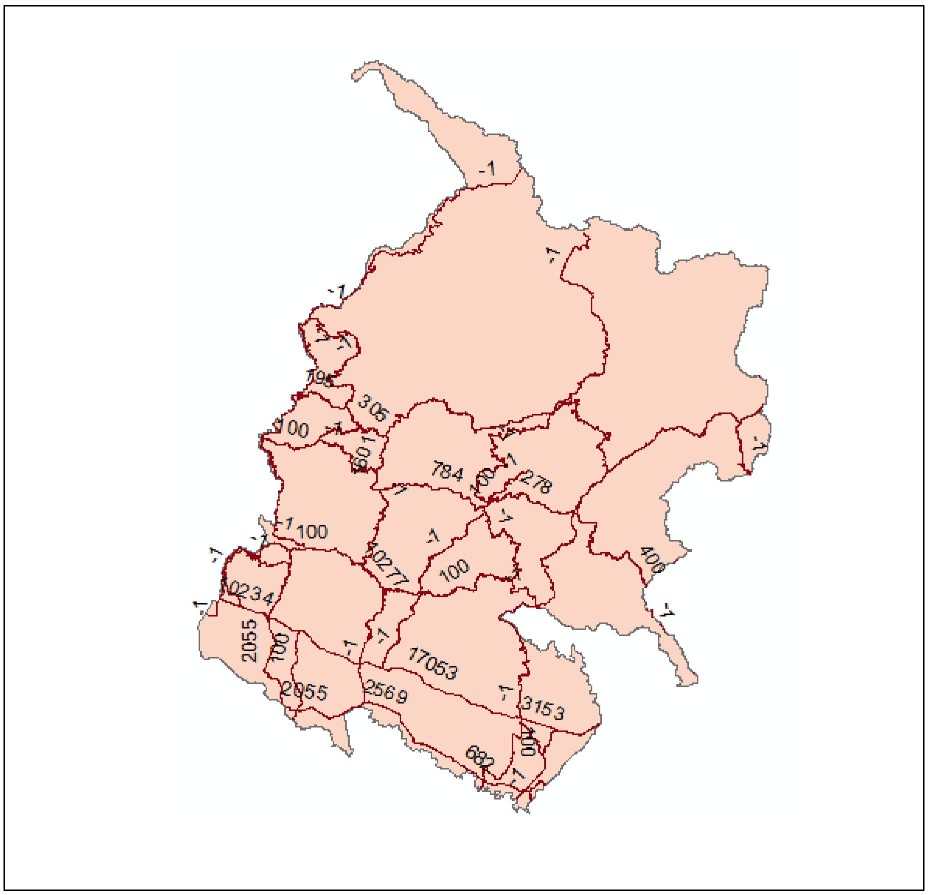


Figure 14 Sudurpaschim Province

The research aimed to conduct a comprehensive study on energy demand modeling and emission forecasting in the transportation sector of Sudurpaschim Province, Nepal. The region was selected as the study site due to its unique socio-economic, geographical, and transportation characteristics, which made it an ideal representative for examining energy consumption patterns and environmental impacts within the context of Nepal's sustainable development goals.

4.2 Sample Size Determination

In regards to the data collection regarding the energy consumption in transportation sector, number of vehicles currently in operating condition is considered as the population and an individual unit of vehicle was considered as the sample. The number of registers vehicles in Sudurpaschim province is shown in Table *5*.

Table 5 Number of vehicles registered in Sudurpaschim province of Nepal

SN	Vehicle type	Number	% share
1	Motorcycle	111,788	72.97%
2	Car	4,003	2.61%
3	Jeep	1,860	1.21%
4	Bus	3,373	2.20%
6	Auto rickshaw	6,954	4.54%
7	E rickshaw	5,577	3.64%
8	Truck, Crane, Dozer	2,567	1.68%
9	Tractor, Power tiller	1,7042	11.12%
		153,194	

The sample size was determined using the number of vehicles using the Krejcie Morgan formula by the parameters stated in the able below.

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

Table 6 Sample size determination parameters

Parameter	Value
χ square for specific confidence level (95%)	3.841
Probability of success	0.5
Probability of failure	0.5
Margin of error	0.05
Total population	153,194
Total sample size	380
Non response rate	1%
Total sample size with non-response rate	383

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

or, $n = \frac{3.841*153194*0.5*(1-0.5)}{0.05^2*(161706-1)+3.841*0.5*(1-0.5)}$

$\therefore, n = 383$

For 90% of the sample size;

$\therefore, n = 345$

The overall sample size has been calculated using the Krejcie & Morgan sampling formula considering the population size as 153,194 at 95% confidence interval with a probability of success of 50, margin of error at 5% and non-response rate of 5%. The overall sample size thus is calculated to be 383. The data for 90% of the calculated sample size was taken. Therefore the sample size for the research was considered to be 345.

The calculated sample size has been further divided into different types of vehicles. The owners of these vehicles have been interviewed for data collection. For better consistency at least 3 number of vehicles by each category has been considered for the survey. The detail sample size of different vehicles for data collection is shown in Table 7.

Table 7 Sample size in case of different vehicles

SN	Vehicle type	Number	Operating Factor	No. of vehicles operating	Sample size
1	Motorcycle	111788	0.7	78251	235
2	Car	4003	0.8	3226	10
3	Jeep	1860	0.8	1488	4
4	Bus	3373	0.31	1045.	3
6	Auto rickshaw	6954	0.91	6328	19
7	E rickshaw	5577	0.91	5075	15
8	Truck, Crane, Dozer,	2567	1	2567	8
9	Tractor, Power tiller	17042	1	17042	51
		153,194		115,023	345

4.3 Primary Data Collection on Vehicle Characteristics

Data collection involved administering questionnaires to vehicle owners within Sudurpaschim Province. The questionnaires were designed to gather specific information regarding vehicle characteristics such as mileage, average occupancy, and annual distance traveled. This approach ensured that relevant data directly from the region's vehicle owners were obtained, enabling a comprehensive understanding of transportation patterns and facilitating accurate energy demand modeling and emission forecasting.

The survey data that was gathered is compiled and is presented in Table 8 that providing a comprehensive reference for the study. The table shows the vehicle characteristics different vehicles. Average occupancy is highest for bus/minibus (26) followed by jeep (3.75), car (2.6), e-rickshaw (2.5) and two wheelers (1.6).

Table 8 Vehicle characteristics obtained from survey

SN	Vehicle type	Mileage	Unit	Annular distance (km)	Average Occupancy (No. of passenger)	Average Load (tons)
1	Bus	12.31	Km/L	65400	26	
2	Car	8.6	Km/L	10890	2.6	
3	Jeep	8.6	Km/L	10890	3.75	
4	Auto rickshaw	20	Km/L	15000	2.5	
5	Truck, Crane, Dozer	3.33	Km/L	35617	-	6
6	Tractor, Power tiller	5.9	Km/L	15617	-	3
7	Two wheeler	46.68	Km/L	6501	1.6	
8	E rickshaw	1.4	KWH/ 100km	10600	2.5	

4.4 Baseline Scenario

This sections explains about the present scenario of transportation sector in Sudurpaschim province of Nepal. The data obtained from the survey was modeled into the energy consumption and various other scenarios. The data about the transport sector in the base year i.e., 2022 was analyzed on different basis including the number of vehicles, the modal split on the basis of ownership, vehicle characteristics like mileage, average occupancy, average load, annular distance travelled were obtained by the primary data collection method of sample survey, and energy consumption by fuel type, by vehicle type etc.

4.4.1 Registered Vehicles

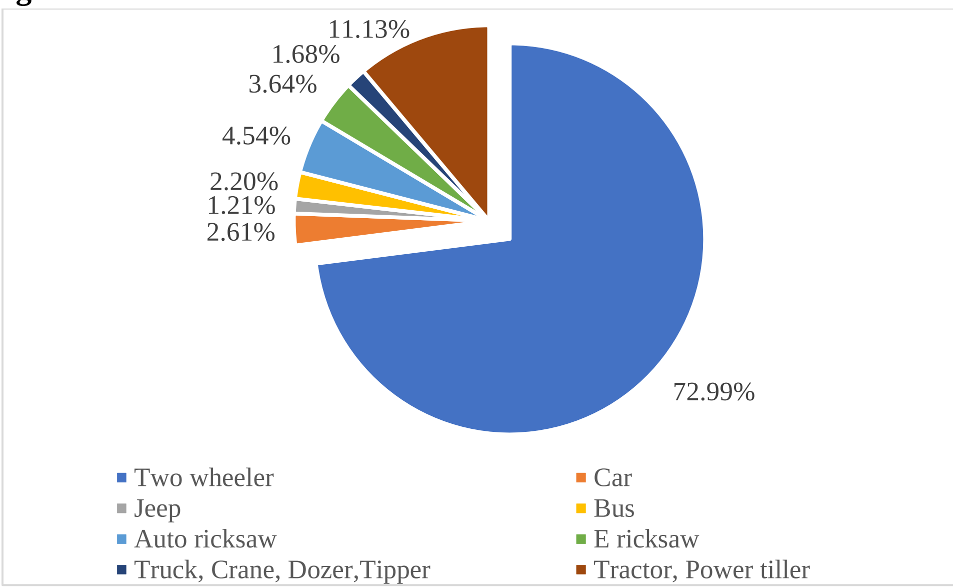


Figure 15 Share of registered vehicles in Sudurpaschim province

In the base year, the total number of registered vehicles in the province was 153,194. The transport sector of the province was characterized by a dominant presence of two wheelers, constituting the highest share at 83.68% of the total vehicles in Sudurpaschim Province. The share of vehicles in Sudurpaschim. Is illustrated in Figure 15.

4.4.2 Share of Vehicle Ownership

Similarly, the vehicle ownership was analyzed on the basis of data provided by the DOTM, Dhangadhi. The data suggested that the highest share of vehicle ownership was with the private sector comprising 87.57% followed by public vehicles with 11.32% and institutional ownership with 2.16%. The vehicle ownership split in Sudurpaschim province is illustrated in Figure 16.

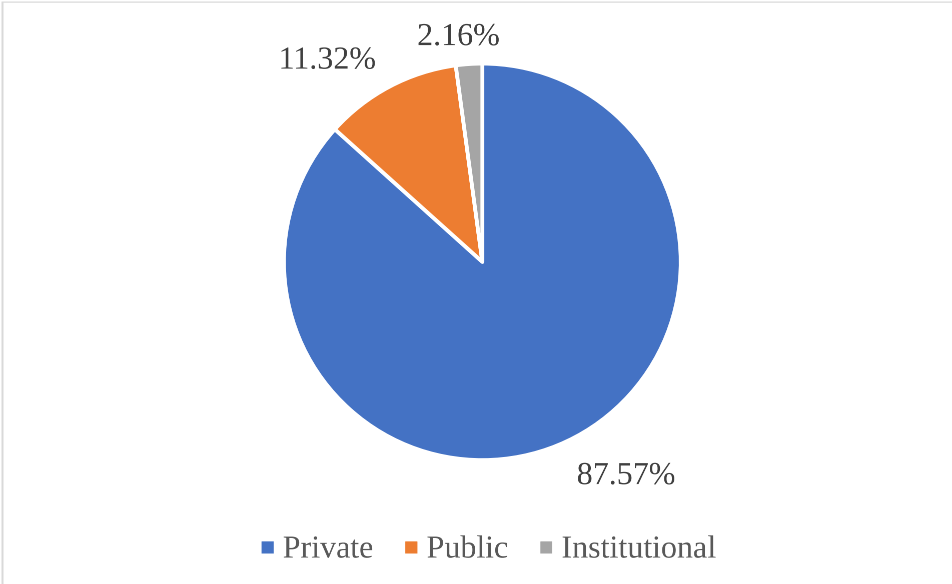


Figure 16Vehicle ownership split in Sudurpaschim province

4.4.3 Energy Consumption by Fuel type

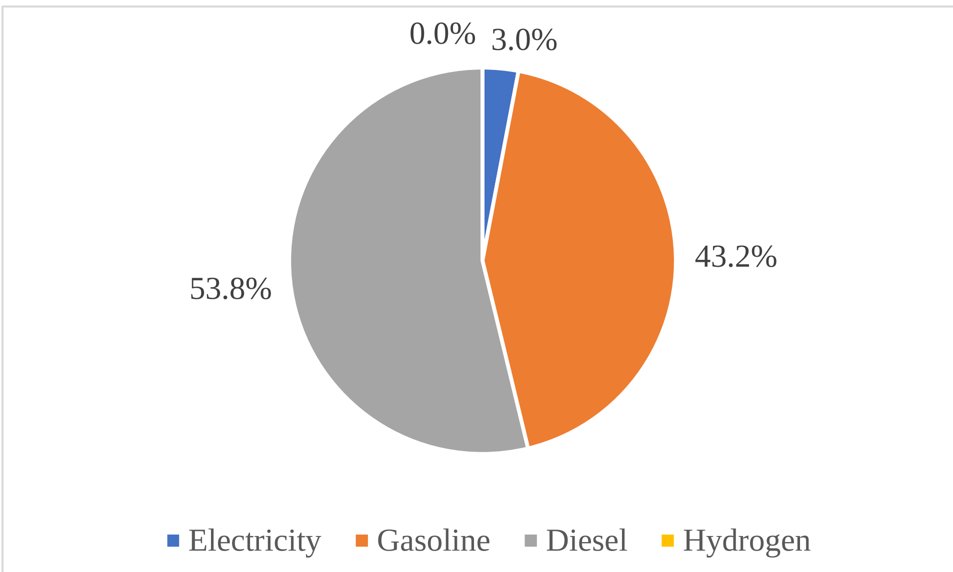


Figure 17 Share of energy consumption by fuel type

The survey revealed that the predominant source of energy consumption was diesel, accounting for 53.8% of the total energy consumption by transportation sector in the province, followed by petrol at 43.2% and finally electricity at 3.01%. The energy consumption share in transportation sector of Sudurpaschim is shown in Figure 17.

4.4.4 Energy Consumption by Vehicle Type

According to the survey conducted during this study, the total transport sector related energy consumption in Sudurpaschim province is found to be 2.61 PJ which was calculated using equation 4. The survey revealed that the predominant vehicle of energy consumption was two wheeler accounting for (37.59%) followed by bus accounting for (21.36%) followed by Tractor and Power Tiller, accounting for (18.48%) of the total, followed by truck, crane dozer, Excavator, tipper at (7.82%), followed by car at car at (5%) auto rickshaw at (4.45%), followed by e rickshaw at (2.95%) followed by jeep (2.33%), and others. The energy consumption by vehicle type in transportation sector in Sudurpaschim province is illustrated by Figure 18.

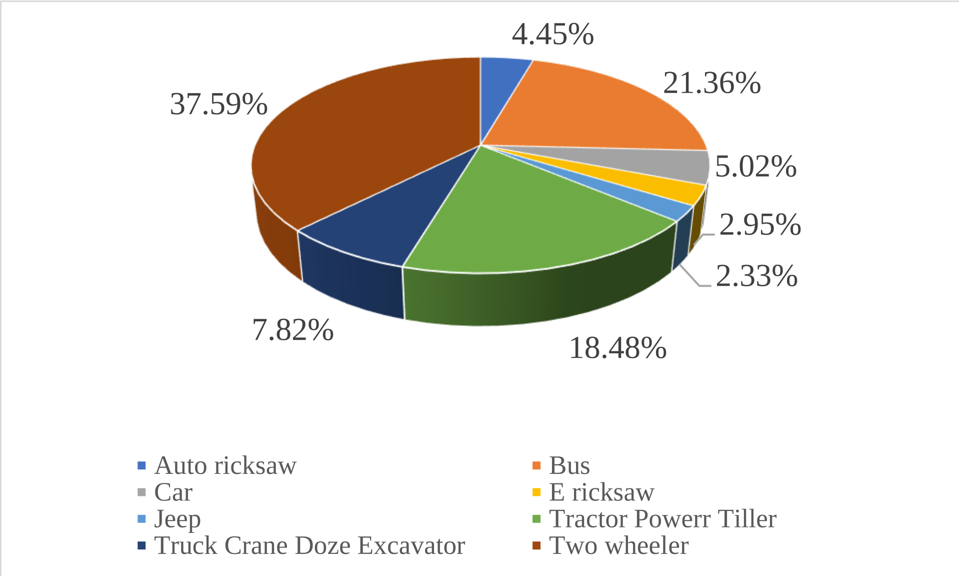


Figure 18 Share of energy consumption by vehicle type

The figure above illustrates the energy consumption by vehicle type in transportation sector in Sudurpaschim province.

4.4.5 Sectoral Energy Consumption in Transport Sector

Similarly, energy consumption in transportation sector on the basis of three different sectors was analyzed and compared. It was found that highest amount of energy was consumed by private sector at (26.63%), followed by public sector at (69.13%), and institutional sector at (4.25%) in Sudurpaschim province.

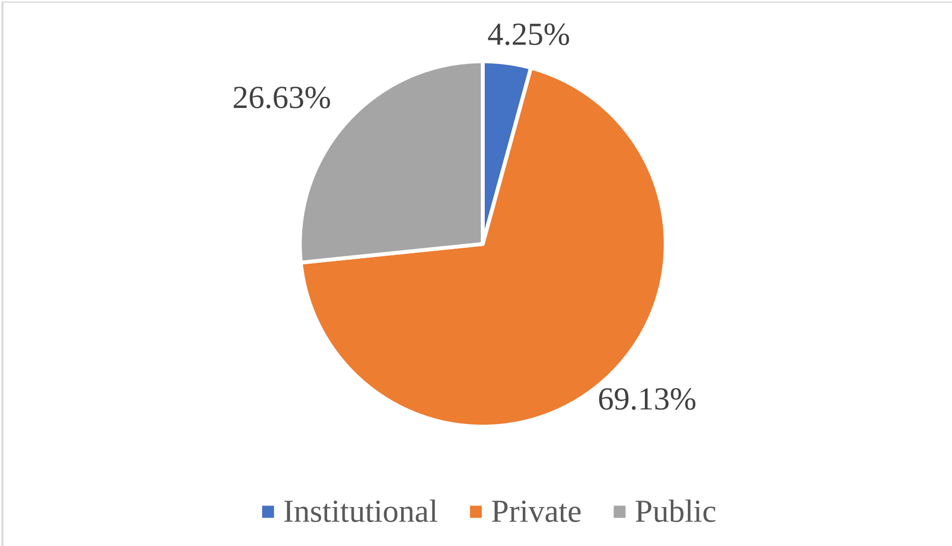


Figure 19 Sectoral energy consumption in Sudurpaschim province

The share of energy consumption in transportation on the basis of different sectors namely private, public and institutional is illustrated in Figure 19.

4.5 Passenger Mobility Characteristics

The graph shown below show comparison between various parameters of different vehicles. Average occupancy is highest for bus (26) followed by jeep (4.75), car (2.6), e-rickshaw (2.5) and motorcycles (1.26). Similarly, energy intensity per passenger km is highest for motorcycles at car 0.94 MJ and lowest for e-rickshaw at 0.14 MJ. In case of passenger km per vehicle, the highest value is for bus and lowest is for e rickshaw. The energy per person of a car is higher than that of motorcycle, bus, jeep, and auto rickshaw and e rickshaw. The passenger mobility characteristics is further illustrated in Figure 20.

4.6 Freight Mobility Characteristics

Similarly, Figure below demonstrates the comparison between various parameters of different freight vehicles. The average load carried is highest for Truck/minitruck (6.86 tonnes) and lowest for pickups (1.25 tonnes). Similarly, energy intensity per ton km is highest for tractor (6.72 MJ) and lowest for truck/minitruck (1.65). Also, the ton km per vehicle is highest for truck/minitruck and least for tractors. The energy intensity per ton of load carried is highest for tractor and lowest for truck/minitruck. The freight mobility characteristics are further illustrated in Figure 21.

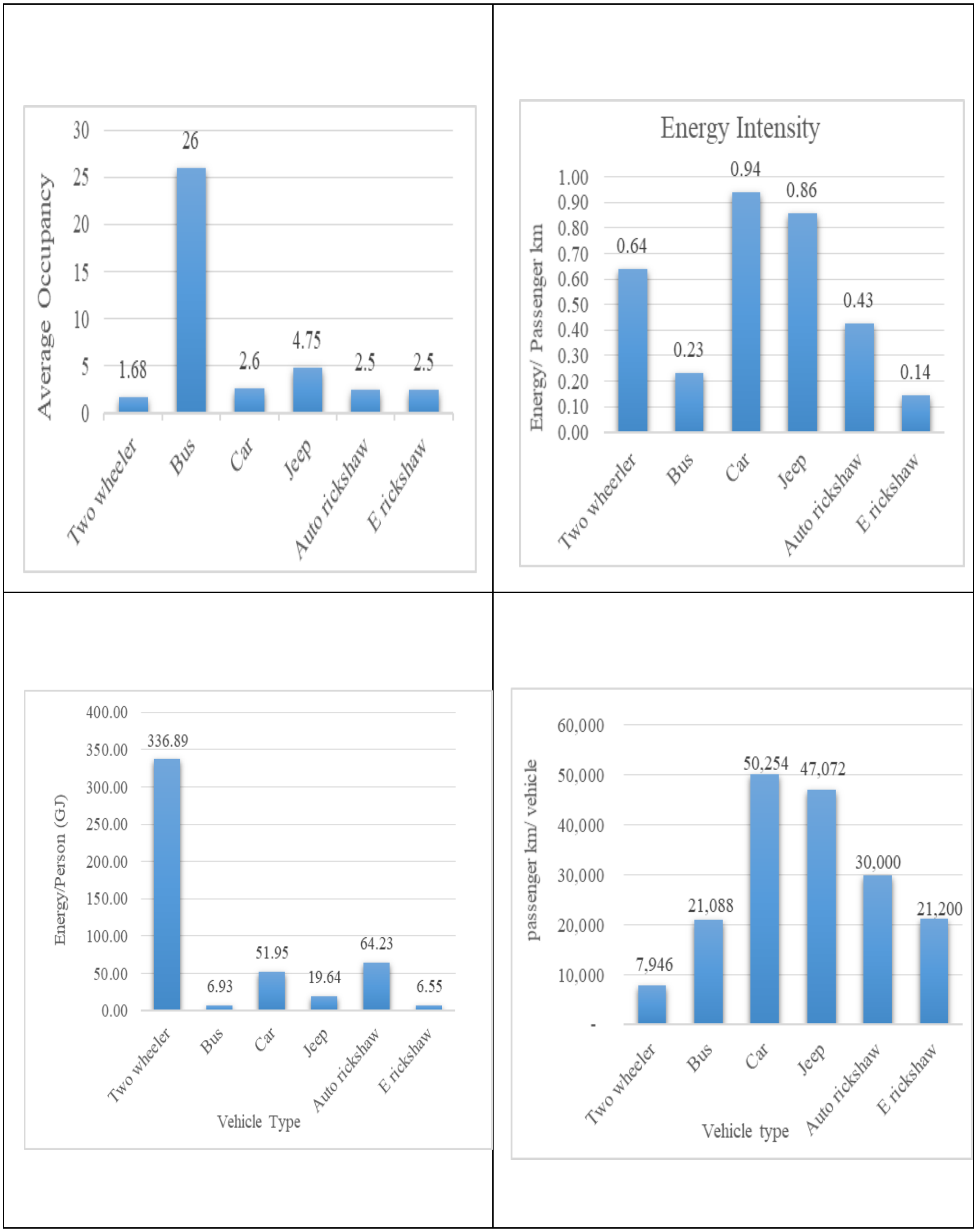


Figure 20 Passenger mobility characteristics

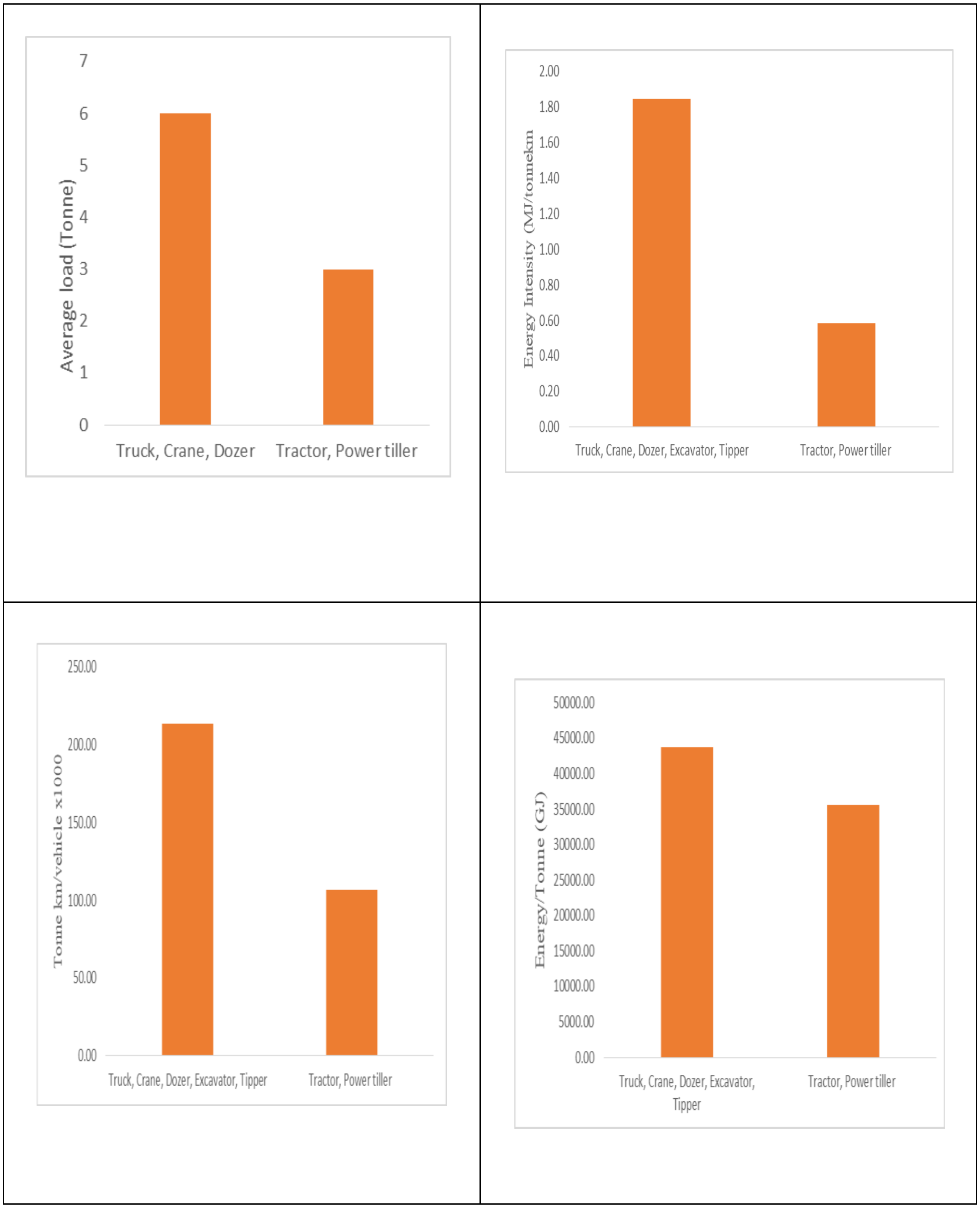


Figure 21 Freight mobility characteristics

4.7 Scenario Development

The three scenarios developed in this study were:

- Business as Usual (BAU)
- Nationally Determined Contribution (NDC)
- Long Term Strategy (LTS)

4.8 Energy Service Demand Projection

Energy service demand is the one of the essentials for forecasting the energy consumption as well as emission. In the study, passenger km (for passenger vehicles) and tonne km (for freight vehicles) have been taken as energy service demands. The service demand has been calculated using the formula shown in Equation 5.

The energy projection was done using LEAP (Low Emission Analysis Platform) model. The base year considered in this study for energy demand analysis is 2022 and the energy was forecasted up to 2050 at the interval of 5 years. For the base year, the energy model was developed based on the data collected and analyzed.

.

4.9 Business as Usual (BAU scenario)

4.9.1 Total Energy Demand

The business as usual (BAU) scenario has been developed based on the historical trend of fuels used in different vehicles in Sudurpaschim province. The energy consumption in this scenario has been forecasted to reach 2.6 PJ by 2025 and 7.34 by 2050 calculated by using equation 5. The energy demand CAGR in this scenario is projected to be approximately 3.8%.

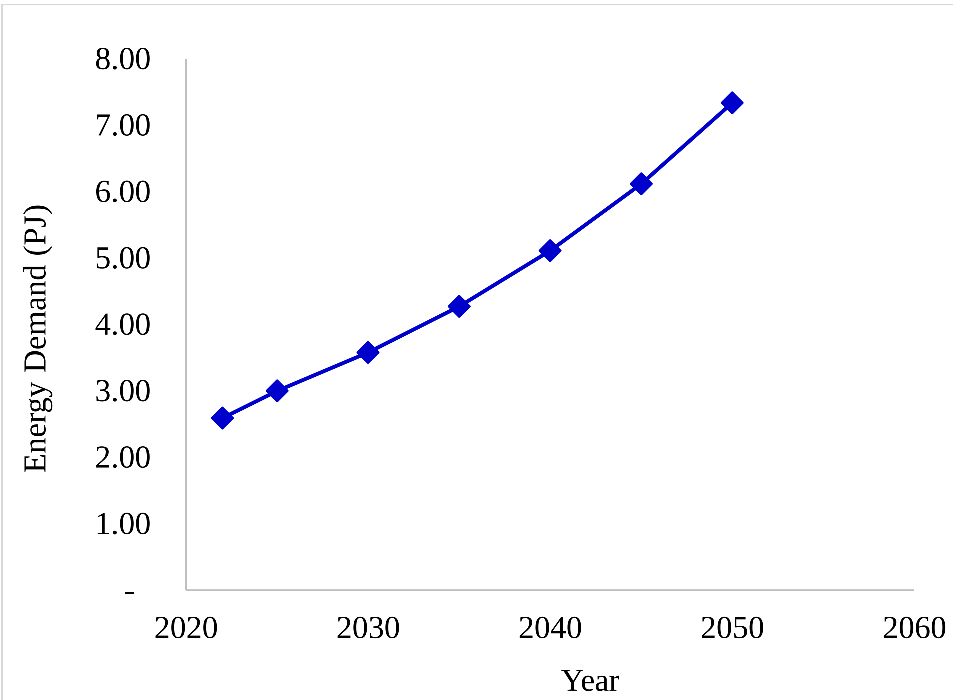


Figure 22 Energy demands demand from 2025 to 2050 in BAU scenario

The total energy consumptions of transportation sector of Sudurpaschim province from base year to 2050 is shown in Figure 22.

4.9.2 Energy Demand by Sectors

The vehicles registered in Sudurpaschim province are under various categories based on the ownership of the vehicles. The major categories are:

- Private
- Public

- Institutional

The consumption of energy by these sectors is forecasted on the basis of historical trends. The private sector is the major consumer of energy with 69.13%, followed by public sector at 26.63% and institutional sector at 4.25% in the base year. In the final year of projection, i.e., 2050. In 2050, the private sector is projected to consume 65.19% of the energy, followed by public sector at 30.21% and institutional sector at 4.60 %.

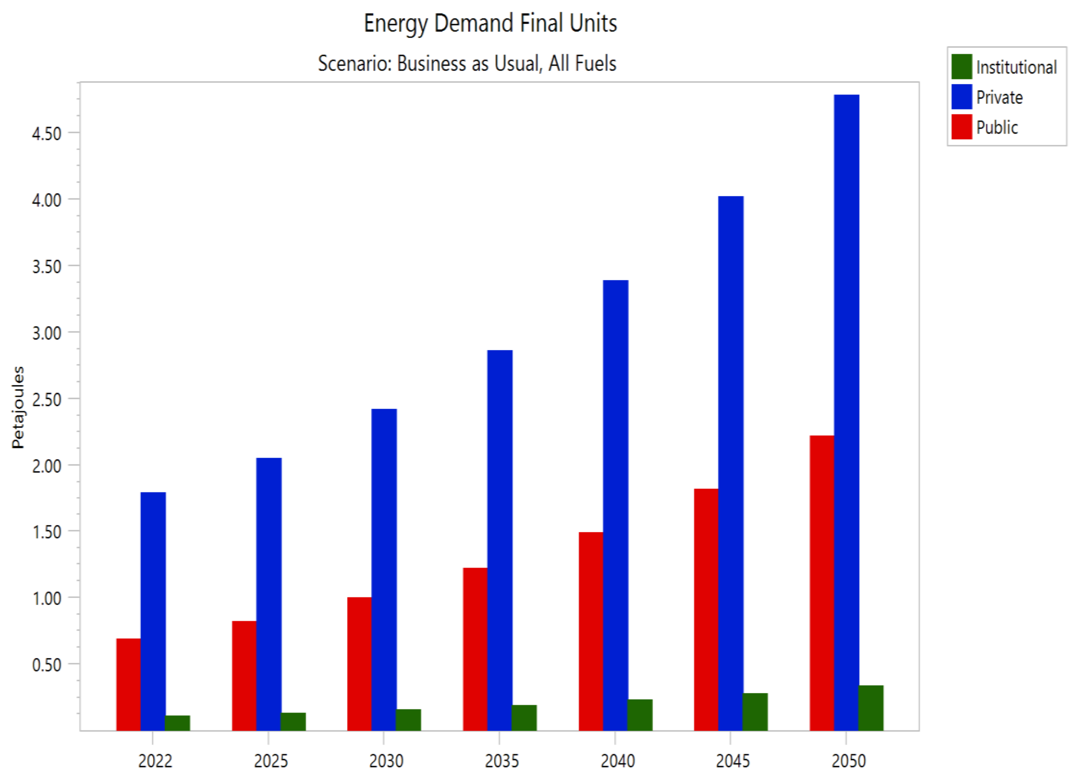


Figure 23 Sectoral energy demand from 2025 to 2050 in BAU scenario

The distribution of energy demand under various categories of ownership in the BAU scenario is shown in Figure 23.

4.9.3 Energy Demand by Fuel Type

In business as usual scenario, the demand for diesel is expected to rise at a CAGR of 4.25%, petrol by 3.33% and electricity by 4.25% over the period of 28 years. The energy consumption by fuel type is illustrated by Figure 24 and Figure 25.

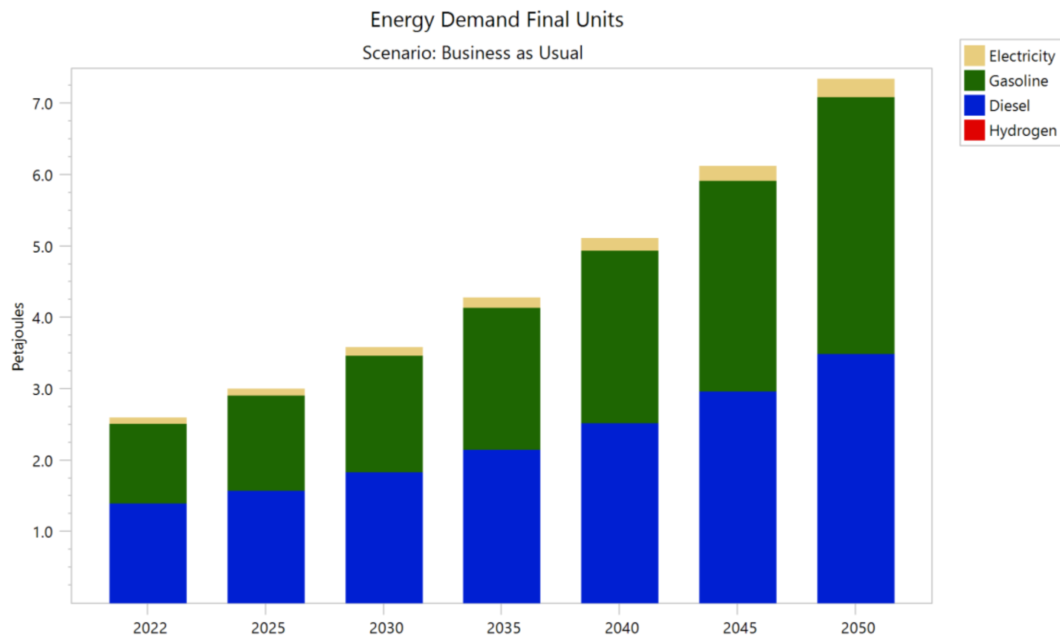


Figure 24 Energy consumption by fuel type from 2022 to 2050 in BAU scenario

With the change in the consumption pattern, the energy mix in the transportation sector in Nepal will also change. In 2022, petrol accounted for 43.23% and diesel for 53.79% of the mix while the share of petrol and diesel in the 2050 is forecasted to become 35.70% and 47.50%.

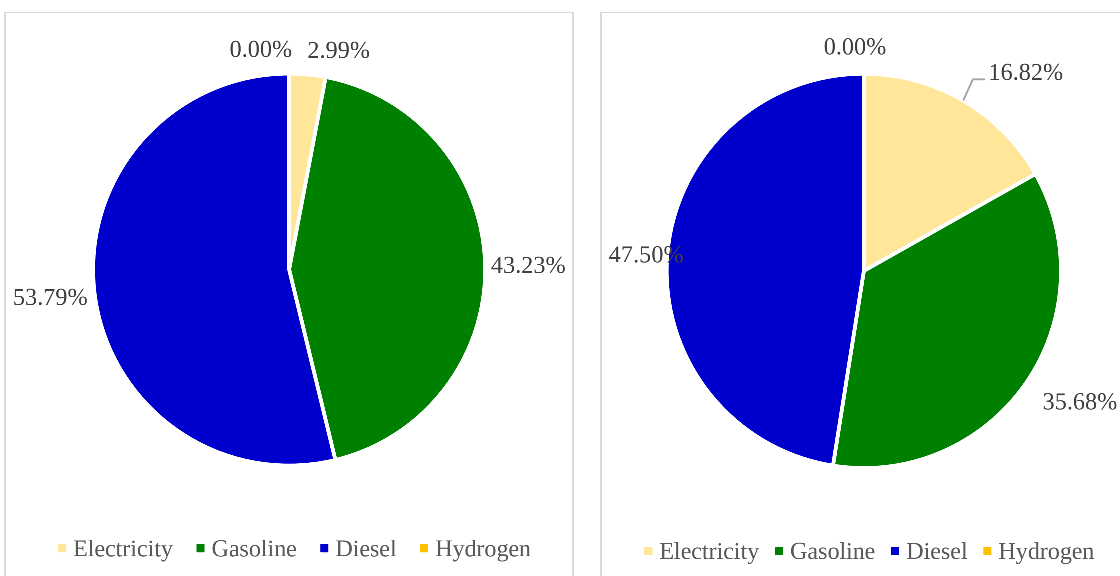


Figure 25 Share of fuel in 2025 (left) and 2050 (right) in BAU scenario

4.9.4 Energy Demand by vehicle type

Over the forecasted timeframe, there will be modular shift two wheeler will continue to dominate energy consumption, with anticipated energy demand reaching 0.98 PJ by 2025 and 3.13 PJ by 2050. Similarly, tractors are projected to exhibit an energy demand of 0.48PJ by 2025 and 0.85 PJ by 2050. Moreover, the energy demand for trucks is estimated to be 0.20 PJ by 2025 and 0.85PJ by 2050. Additionally, buses are anticipated to manifest an energy demand of 0.66PJ by 2030 and 1.46 PJ by 2045, and cars are predicted to reach 0.16 PJ by 2030 and 0.42 PJ by 2050. The energy demand of different vehicles in the BAU scenario is shown Table 9.

Table 9 Energy consumption by vehicle type in BAU scenario

Energy Demand Final Units								
Scenario: Business as Usual								
Demand: Transport								
Units: Petajoules (PJ)								
Vehicle type	2022	2025	2030	2035	2040	2045	2050	Total
Auto rickshaw	0.12	0.14	0.17	0.20	0.25	0.30	0.37	1.55
Bus	0.55	0.66	0.81	0.98	1.20	1.46	1.78	7.44
Car	0.13	0.16	0.19	0.23	0.28	0.34	0.42	1.75
E rickshaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Jeep	0.06	0.07	0.09	0.11	0.13	0.16	0.19	0.81
Tractor Power Tiller	0.48	0.51	0.56	0.62	0.69	0.76	0.85	4.47
Truck Crane Dozer	0.20	0.22	0.24	0.26	0.29	0.32	0.36	1.89
Two wheeler	0.98	1.16	1.42	1.73	2.11	2.57	3.13	13.08
Total	2.59	3.00	3.58	4.27	5.11	6.12	7.34	32.02

The detailed data regarding the energy demand projection and emission forecast is shown in ANNEX I.

4.10 Nationally Determined Contribution (NDC scenario)

The sustainable development scenario has been developed based on the targets of the NDC of Nepal. The major consideration in this scenario are:

- Sales of private passenger electric vehicles (including two-wheelers) in 2025 to be 25% of the total sales
- Sales of public passenger electric vehicles (excluding e-rickshaws and electric tempos) in 2025 will be 20% of total sales
- Sales of private passenger electric vehicles (including two-wheelers) in 2030 will be 90% of the total sales
- Sales of public passenger electric vehicles (excluding e-rickshaws and electric tempos) in 2030 will be 60% of total sales
- There is no change in the energy consumption pattern of freight vehicles

4.10.1 Total Energy Demand

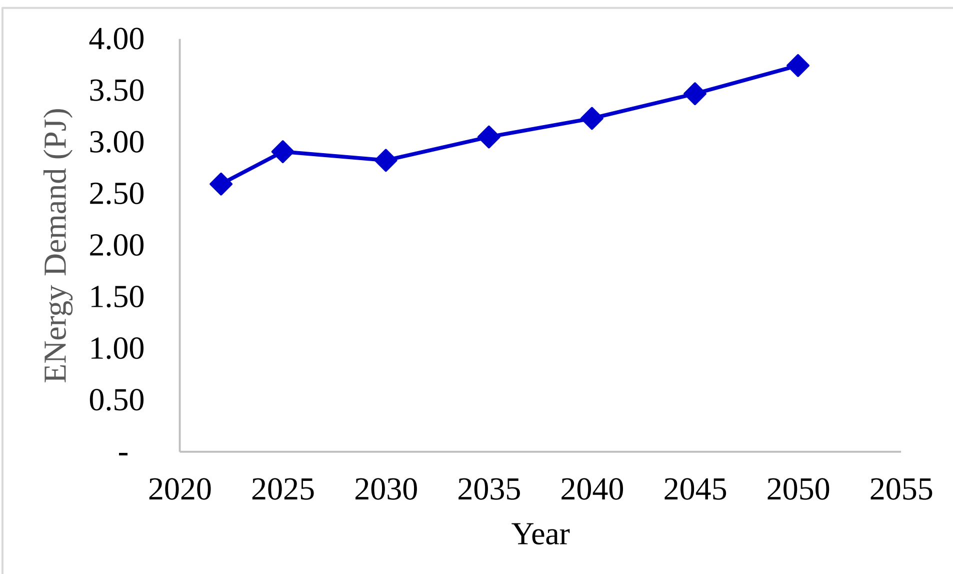


Figure 26 Energy consumption demand from 2022 to 2030 in NDC scenario

The sustainable development (SD) scenario has been developed based on the historical trend of fuels used in different vehicles in Nepal along with the targets of the second Nationally Determined Contribution (NDC). The energy consumption in this scenario has been forecasted to reach 2.59 PJ by 2030 and 3.74 PJ by 2045. The energy demand CAGR in this scenario is projected to be 1.32%. The total energy consumptions for different years are shown in Figure 26.

4.10.2 Sectoral Energy Demand

The consumption of energy by these sectors is forecasted on the basis of historical trends. The private sector is the major consumer of energy with 66.13%, followed by public sector at 29.67% and institutional sector at 4.19% in the 2030. In the final year of projection, i.e., 2050, the private sector is projected to consume 57.28% of the energy, followed by public sector at 38.53% and institutional sector at 4.19%. The distribution of energy demand under various categories of ownership in the NDC scenario is shown in Figure 27.

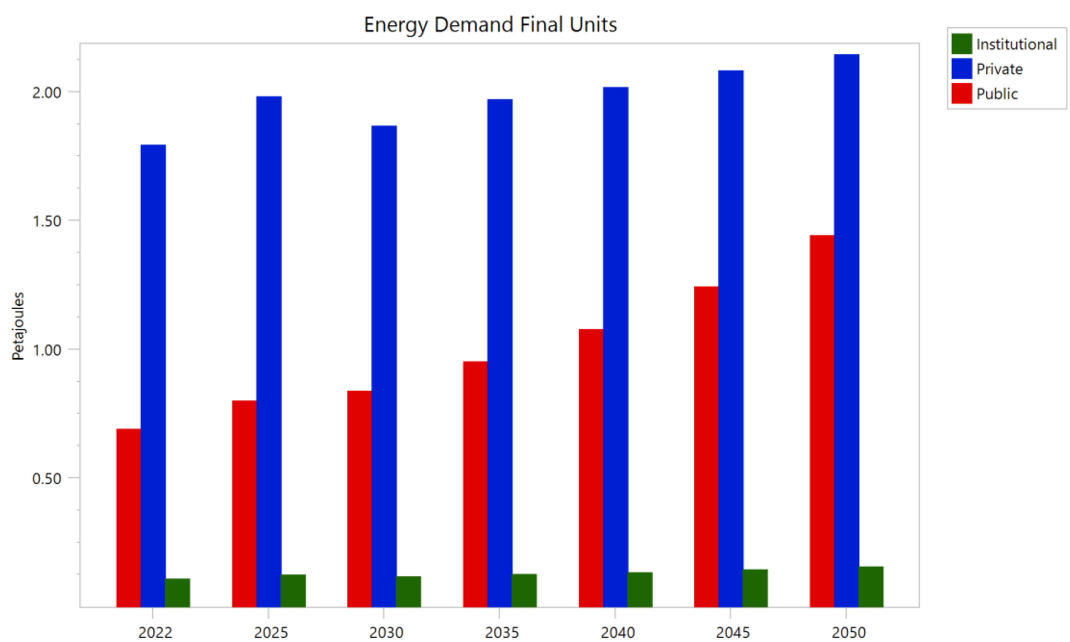


Figure 27 Sectoral Energy consumption demand from 2022 to 2050 in NDC scenario

4.10.3 Energy Demand by Fuel Type

In the context of sustainable development, the demand for diesel is expected to decline at a CAGR of 4.29%, while petrol has been projected to decline by 2.35%. In contrast, electricity as a transportation fuel is anticipated to experience a significant growth at a CAGR of 12.86%.

Additionally, this increase in electricity demand and simultaneous decrease in petrol and diesel consumption can be attributed to the widespread adoption of electric vehicles, as pledged in the Nationally Determined Contributions (NDC) towards achieving sustainable development goals. The overall energy consumption by fuel type is shown in Figure 28.

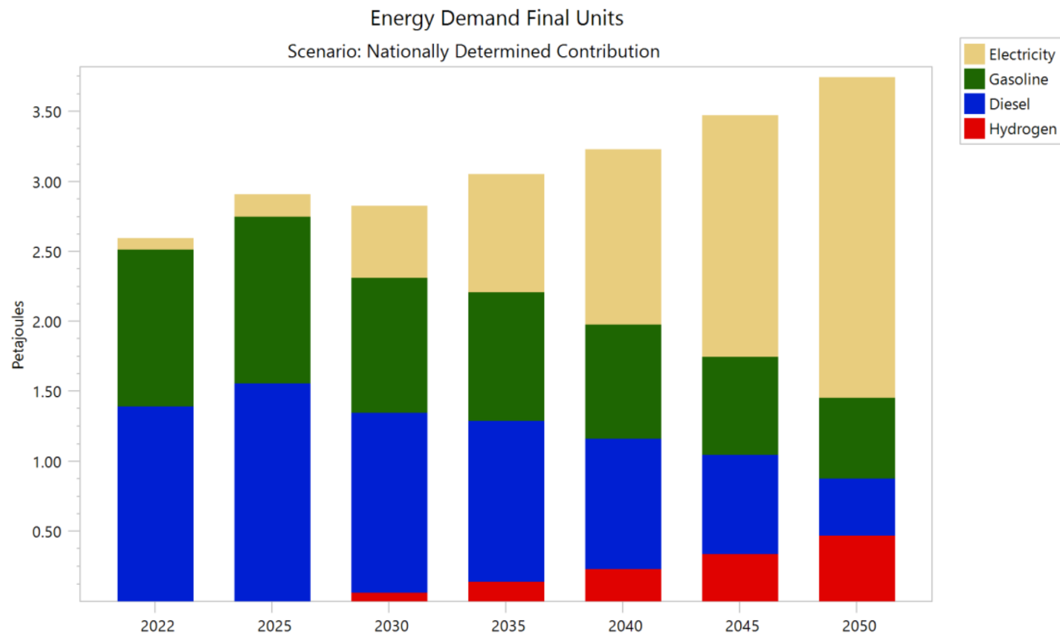
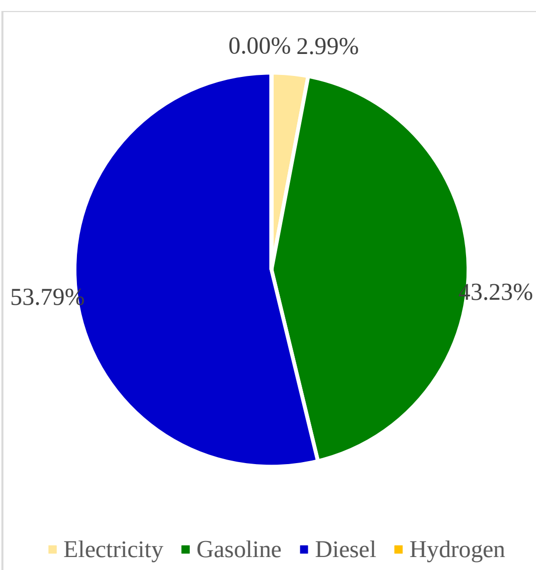


Figure 28 Energy consumption demand from 2022 to 2050 in NDC scenario



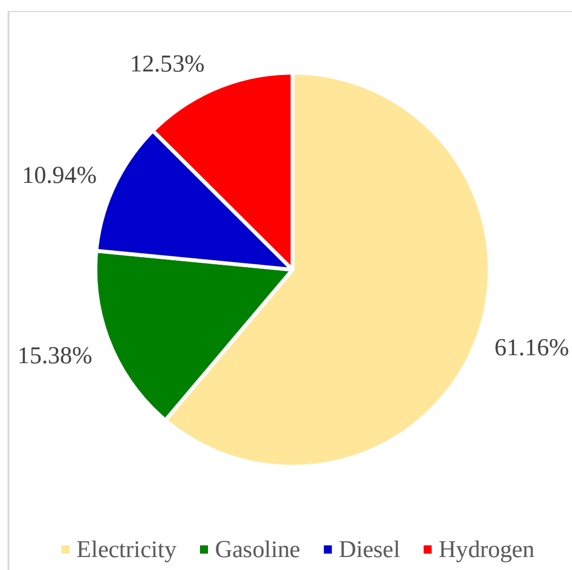


Figure 29 Share of fuel in energy demand in 2022 (left) and 2050 (right)

The share of fuel was covered maximum by diesel at 53.79% followed by petrol at 43.23%, electricity at 2.99% and hydrogen is yet to make its place in the fuel share of energy demand in the base year. In contrast to this, the share of fuel was covered maximum by electricity at 61.16% followed by petrol at 15.38%, diesel at 10.94% and hydrogen which is expected to be used as a fuel from 2030 onwards is projected to reach 12.53% is yet to make its place in the fuel share of energy demand in 2050. The energy mix of different fuels in the year 2022 and 2050 is shown in Figure 29.

4.10.4 Energy Demand by Vehicle type

Over the forecasted timeframe, there will be modular shift two wheeler will continue to dominate energy consumption, with anticipated energy demand reaching 1.10 PJ by 2030 and 0.77 PJ by 2045. Similarly, tractors are projected to exhibit an energy demand of 0.51 PJ by 2030 and 0.80 PJ by 2045. Moreover, the energy demand for auto rickshaw is estimated to be 0.13 PJ by 2030 and 0.25 PJ by 2045, while e rickshaw are expected to require 0.11 PJ by 2030 and 0.20 PJ by 2045.

Table 10 Energy consumption demand for different vehicles in NDC scenario

Energy Demand Final Units								
Scenario: Nationally Determined Contribution (NDC)								
Demand: Transport								
Units: Petajoules								
Vehicle type	2022	2025	2030	2035	2040	2045	2050	Total
Auto rickshaw	0.12	0.13	0.15	0.17	0.21	0.25	0.31	1.34
Bus	0.55	0.64	0.64	0.71	0.79	0.88	0.99	5.20
Car	0.13	0.15	0.14	0.14	0.14	0.15	0.15	0.99
E rickshaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Jeep	0.06	0.07	0.07	0.08	0.08	0.09	0.10	0.55
Tractor Power Tiller	0.48	0.51	0.57	0.64	0.71	0.80	0.89	4.59
Truck Crane Dozer	0.20	0.22	0.24	0.27	0.30	0.34	0.38	1.94
Two wheeler	0.98	1.10	0.91	0.90	0.84	0.77	0.69	6.18
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Additionally, buses are anticipated to manifest an energy demand of 0.64 PJ by 2030 and 0.88 PJ by 2045, and cars are predicted to reach 0.15 PJ by 2030 and 0.15 PJ by 2045. The energy demand of different vehicles in the NDC scenario is shown in Table 10.

4.11 Long Term Strategy (LTS scenario)

The net-zero emission scenario has been developed based on the targets of the Long-term Strategy for net-zero emission. The major considerations within this scenario are:

- The passenger vehicles will completely shift to electricity by 2045
- The freight vehicles will completely shift to electricity by 2045

4.11.1 Total Energy Demand

The Long Term Strategy (LTS) scenario has been developed based on the historical trend of fuels used in different vehicles in Nepal. It also encompasses the targets of LTS and motive of net zero emission. The energy consumption in this scenario has been forecasted to reach 2.89 PJ by 2030 and 2.54 PJ by 2045. The energy demand CAGR in this scenario will be 0.14%. The total energy consumptions for different years are shown in Figure 30.

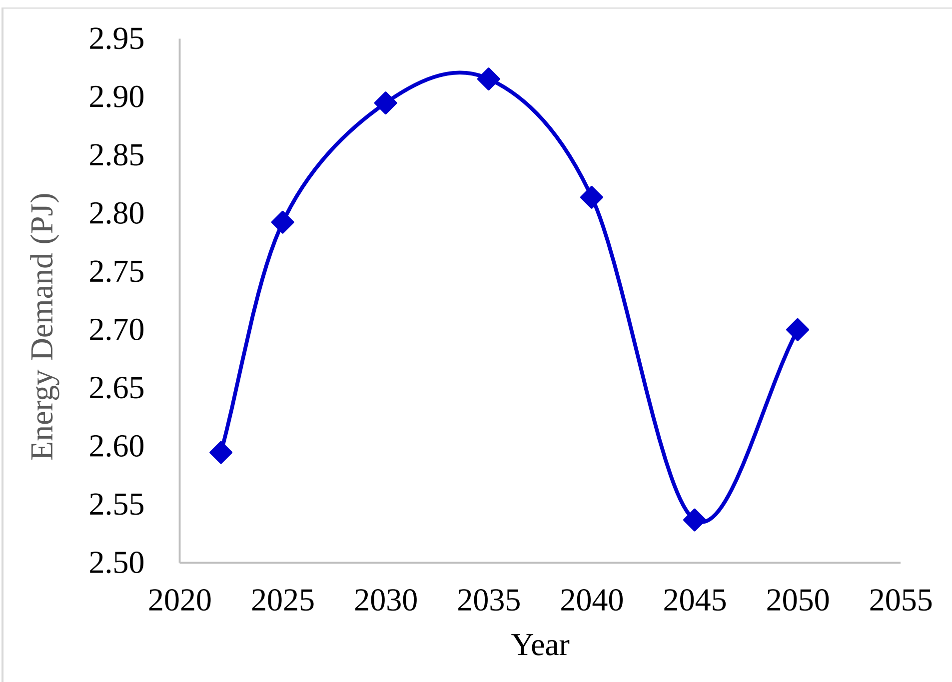


Figure 30 Energy consumption demand from 2022 to 2025 in LTS scenario

4.11.2 Sectoral Energy Demand

The consumption of energy by the sectors is forecasted on the basis of historical trends. In the final year of projection, i.e., 2050, the private sector is projected to consume 52.24% of the energy, followed by public sector at 43.42% and institutional sector at 4.34%.

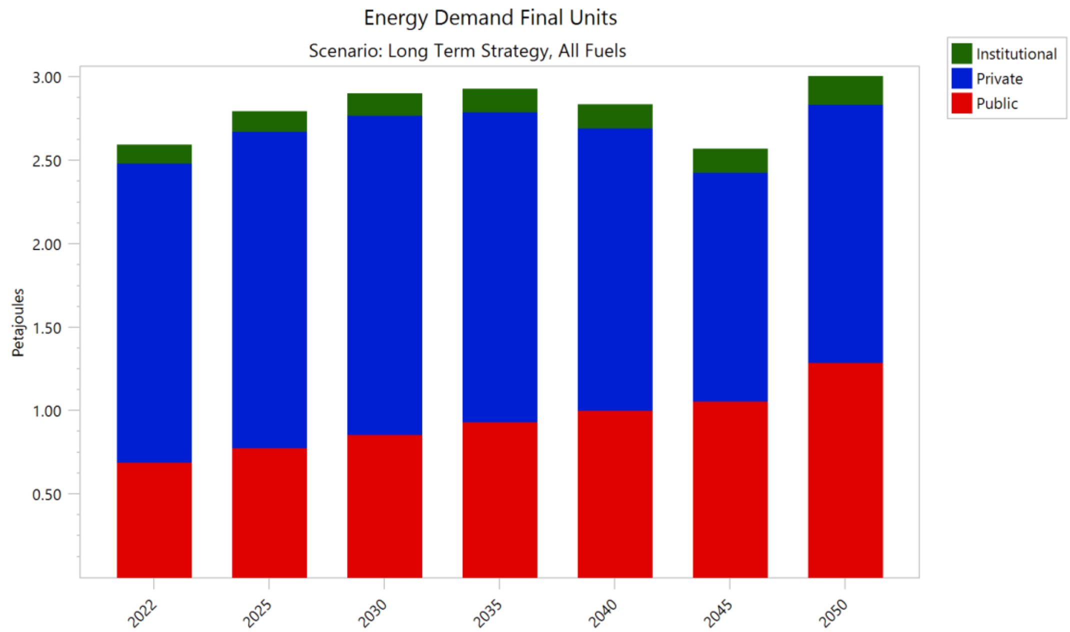


Figure 31 Sectoral energy consumption from 2022 to 2050 in LTS scenario

The distribution of energy demand under various categories of ownership in the LTS scenario is shown in Figure 31.

4.11.3 Energy Demand by Fuel Type

The penetration of various technologies and shifts in the market landscape can significantly impact the distribution of different fuels in the transportation sector. Under Long Term Strategy (LTS) scenario, the demand for petroleum products, specifically diesel and petrol, is projected decline at CAGR of 5.06% and 4.11%, respectively. On the other hand, the demand of electricity as a transportation fuel is expected to grow at a faster rate of 13.20%. Additionally green hydrogen starting from 2030 is projected to rise at a CAGR of 7.59%. The overall energy consumption by fuel type is shown in Figure 32.

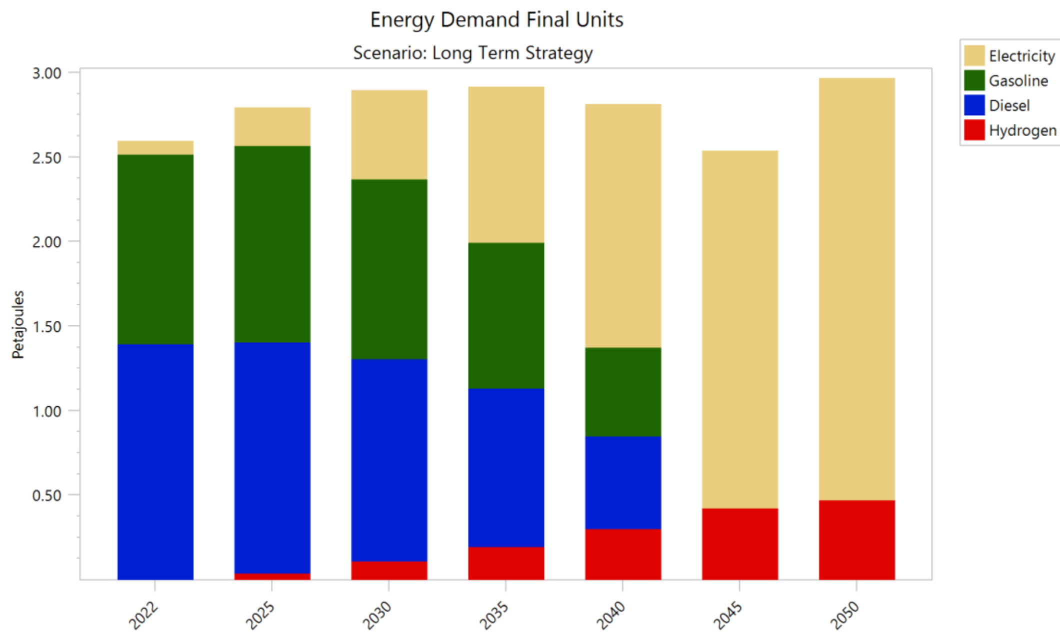


Figure 32 Energy consumption by fuel type from 2022 to 2050 in LTS scenario

This implies that while the demand for electricity and hydrogen as a fuel source will rise, petrol and diesel will continue to decline their dominant position as the primary fuels in the transportation sector of Sudurpaschim province.

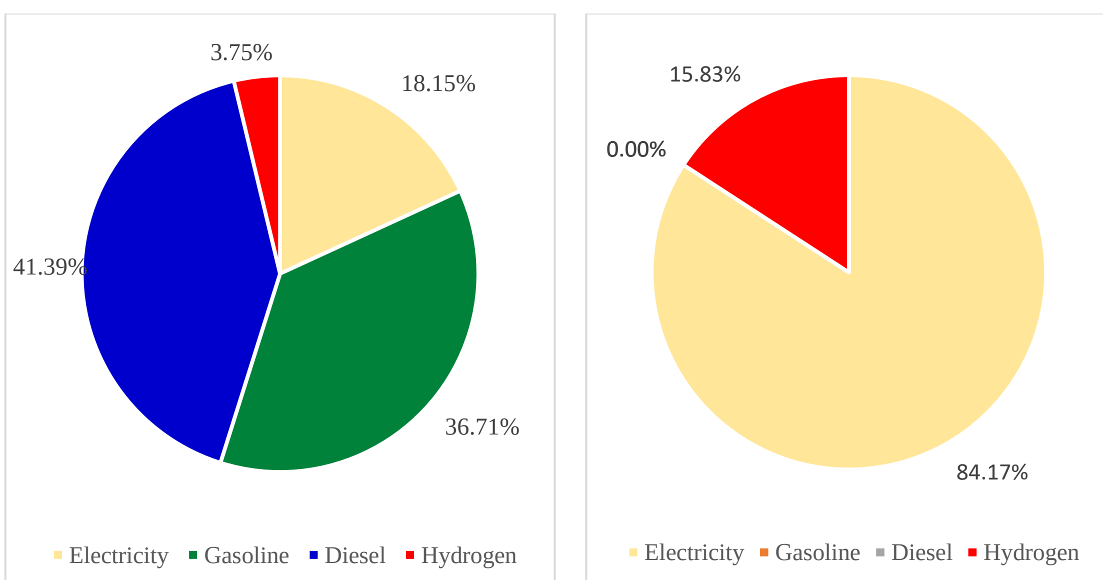


Figure 33 Energy consumption by fuel type from 2030 (left) to 2050 (right) in LTS

With the change in the consumption pattern, the energy mix in the transportation sector in Nepal will also change. In 2030, petrol accounted for 36.71% and diesel for 41.39% of the mix while the share of petrol and diesel in the 2050 is forecasted to phase out. On the other hand the share of electricity and hydrogen in 2030 is forecasted to be 18.15% and 3.75 % respectively which in 2050 is projected to reach 84.17% and 15.83% respectively the share of different fuels in the energy mix of the province is illustrated in Figure 33.

4.11.4 Energy Demand by Vehicle type

In LTS scenario also two wheelers consume 0.98 PJ in 2025 and 0.16 PJ by 2045. Similarly, tractors are projected to exhibit an energy demand of 0.48 PJ by 2030 and 0.89 PJ by 2050. Moreover, the energy demand for trucks is estimated to be 0.20 PJ by 2025 and 0.38 PJ by 2050, while car are expected to require 0.13 PJ by 2025 and 0.09 PJ by 2045. Additionally, buses are anticipated to use an energy demand of 0.55 PJ by 2030 and 0.82 PJ by 2050, and auto rickshaw are predicted to reach 0.12 PJ by 2025 and 0.31 PJ by 2050. The energy demand of different vehicles in the BAU scenario is shown in Table 11.

Table 11 Energy consumption demand by vehicle type in LTS scenario

Energy Demand Final Units								
Scenario: Long Term Strategy								
Demand: Transport								
Units: Petajoules								
Vehicle type	2022	2025	2030	2035	2040	2045	2050	Total
Auto rickshaw	0.12	0.13	0.16	0.18	0.22	0.25	0.31	1.36
Bus	0.55	0.61	0.65	0.68	0.69	0.67	0.82	4.68
Car	0.13	0.14	0.14	0.13	0.11	0.08	0.09	0.82
E rickshaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Jeep	0.06	0.07	0.07	0.07	0.07	0.06	0.08	0.48
Tractor Power Tiller	0.48	0.51	0.57	0.64	0.72	0.80	0.89	4.62
Truck Crane Dozer	0.20	0.22	0.24	0.27	0.30	0.34	0.38	1.95
Two wheeler	0.98	1.02	0.95	0.80	0.54	0.13	0.16	4.57
Total	2.59	2.79	2.89	2.92	2.81	2.54	2.96	19.51

4.12 Emission Forecast

4.12.1 Business as Usual (BAU) scenario

The GHG emission in the base year for the transportation sector is estimated to be 111.7 thousand $MTCO_{2eq}$ at 100 year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 3.41% until 2050. In the final year of projection, the emissions are expected to reach 1,292.9 thousand $MTCO_{2eq}$. The overall GHG emission in the BAU scenario is shown in Table 12.

Table 12 GHG emission from 2022 to 2050 in BAU scenario

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Business as Usual								
Demand: Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
GHG	2022	2025	2030	2035	2040	2045	2050	Total
Carbon Dioxide	106.2	120.1	140.5	164.9	193.8	228.3	269.5	1,223.4
Methane	3.1	3.7	4.5	5.5	6.6	8.1	9.8	41.3
Nitrous Oxide	2.3	2.7	3.2	3.8	4.5	5.4	6.4	28.3
Total	111.7	126.5	148.2	174.1	204.9	241.8	285.8	1,292.9

In a comparative analysis of emissions from various transportation sectors, it was observed that the private transportation sector exhibited the highest emissions, followed by the public transportation sector and then the institutional transportation sector in Sudurpaschim province. This underscored the significant environmental impact of private transportation in comparison to public and institutional alternatives. Addressing the challenges associated with private vehicle emissions could have contributed to more sustainable and environmentally friendly transportation practices.

This private emissions sector accounted for 64.4 thousand $MTCO_{2eq}$ followed by public sector at 41.5 thousand $MTCO_{2eq}$ and institutional sector at 5.8 thousand $MTCO_{2eq}$. In the final year of projection the private sector emissions accounted for 136.9 thousand $MTCO_{2eq}$

followed by public sector at 131.6 thousand $MTCO_{2eq}$ and institutional for 17.2 thousand $MTCO_{2eq}$. The forecast of emission from to 22 to 2050 is shown in Figure 34.

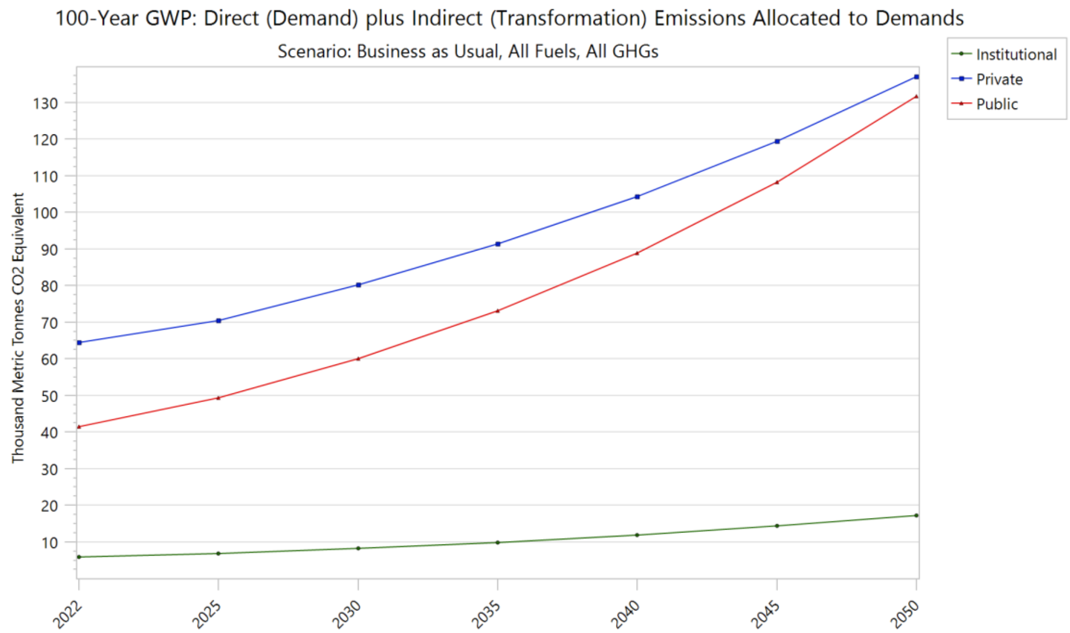


Figure 34 Emissions from different sectors from 2022 to 2050 in BAU scenario

4.12.2 Nationally Determined Contribution (NDC) scenario

For the Nationally Determined Contribution (NDC) scenario, the GHG emission by the transportation sector of Sudurpaschim province is estimated to decline by CAGR of 4.49 %. The GHG emissions in 2022 is projected to be from 106.2 thousand $MTCO_{2eq}$ which is estimated to decline to a value of 28.4 thousand $MTCO_{2eq}$ at 100 year global warming potential (GWP). The detailed value of GHG emissions from 2022 to 2050 for the province is shown in Table *13*.

In this scenario, a notable reduction is projected to be seen in emissions across various sectors, with the private sector decreasing by CAGR 6.95%, the public sector by 2.61%, and the institutional sector by 3.01%. This observed pattern signifies a concerted effort to curtail emissions, with the public sector leading in the magnitude of reduction, followed by the institutional sector, and the private sector displaying the smallest decline.

Table 13 GHG emission from 2022 to 2050 in NDC scenario

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Nationally Determined Contribution								
Demand: Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
GHG	2022	2025	2030	2035	2040	2045	2050	Total
Carbon Dioxide	106.2	114.3	94.9	83.9	67.7	50.4	28.4	545.8
Methane	3.1	3.4	2.7	2.5	2.1	1.9	1.5	17.1
Nitrous Oxide	2.3	2.5	2.1	1.9	1.6	1.3	0.9	12.6
Total	111.7	120.2	99.6	88.3	71.4	53.5	30.8	575.6

The data showing the forecast of GHG emissions is shown in Table 13. The decline of GHG emissions is depicted in Figure 35.

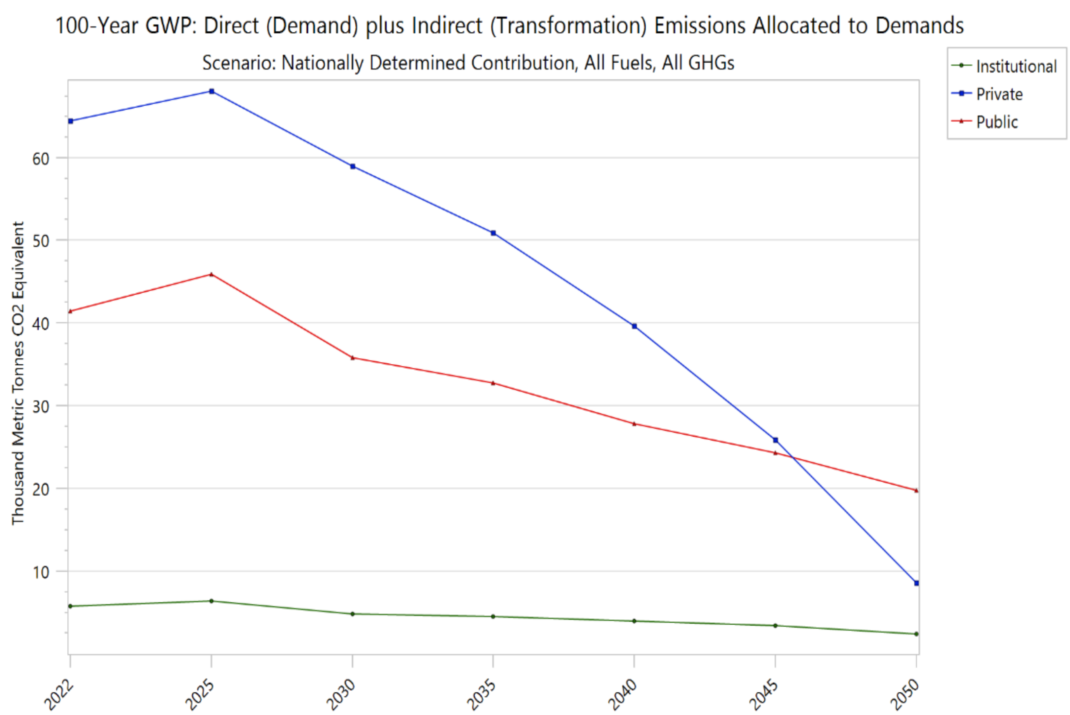


Figure 35 Emissions from different sectors from 2022 to 2050 in NDC scenario

5.12.3 Long Term Strategy (LTS) scenario

For the Long Term Strategy (LTS) scenario, the GHG emission by the transportation sector of Sudurpaschim province is estimated to decline by CAGR of 4.98% up to 2040. But due to the policy implications as per the Long Term Strategy, it is expected that the GHG emission reach net zero by 2045. The GHG emissions in 2022 is projected to be from 106.2 thousand $MTCO_{2eq}$ which is estimated to decline to a value of 42.4 thousand $MTCO_{2eq}$ at 100 year global warming potential (GWP). The detailed value of GHG emissions from 2022 to 2050 for the province is shown in Table 14.

Table 14 GHG emission from 2022 to 2050 in LTS scenario

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Long Term Strategy								
Demand: Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
GHG	2022	2025	2030	2035	2040	2045	2050	Total
Carbon Dioxide	106.2	104.4	91.7	71.7	42.1	-	-	416.1
Methane	3.1	3.2	2.9	2.4	1.4	-	-	13.1
Nitrous Oxide	2.3	2.3	2.1	1.6	1.0	-	-	9.3
Total	111.7	110.0	96.7	75.7	44.6	-	-	438.5

In this scenario, emissions from various sectors demonstrated a continuous decline, measured by from the base year 2022 to 2050. Specifically, the private sector is projected to experience a substantial reduction by CAGR 5.64%, the public sector decreased by 4.15%, and the institutional sector exhibited a decline of 4.40%. This consistent downward trend underscores a committed effort to mitigate emissions over the long term, aligning with the LTS goal of achieving net-zero emissions by 2045. Consequently, by 2045, it is anticipated that emissions across all sectors will reach zero, marking a significant milestone in the pursuit of a sustainable and environmentally responsible future.

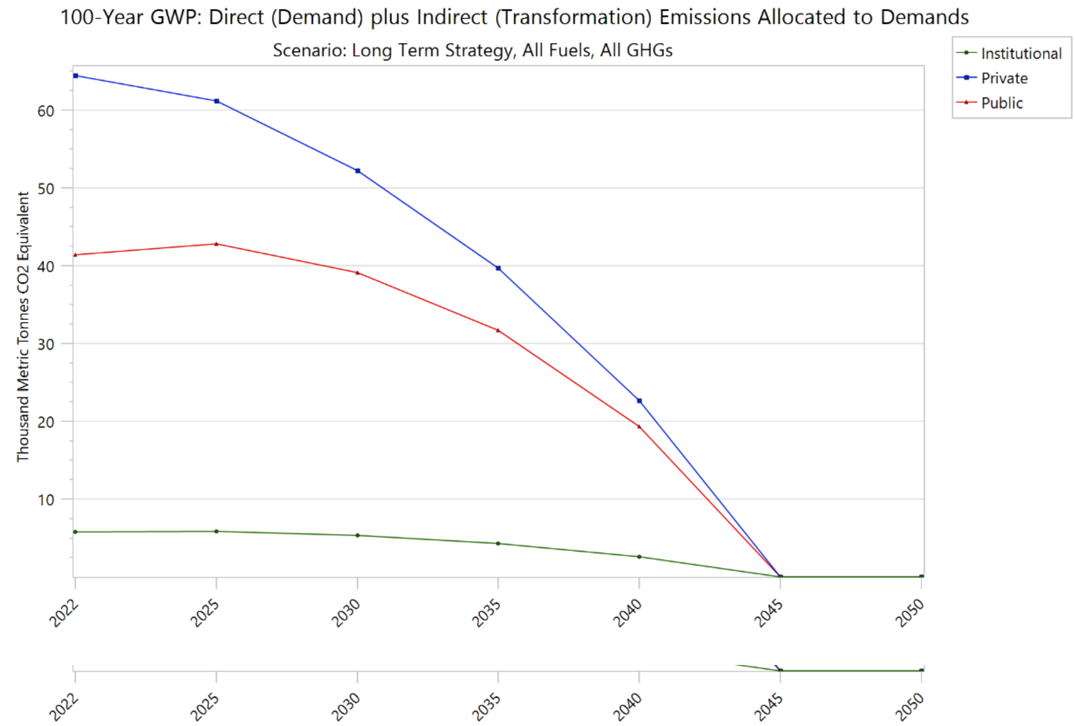


Figure 36 Emissions from different sectors from 2022 to 2050 in LTS scenario

The declining pattern of emissions under the implications of Long Term Strategy is shown in Figure 36.

4.13. Scenario comparison

4.13.1 Energy Demand

The examination of energy demand across three scenarios: Business as Usual (BAU), Nationally Determined Contributions (NDC), and Long-Term Strategy (LTS), yielded insights into their historical trajectories.

In the Business as Usual scenario, energy demand was expected to follow historical patterns, representing a continuation of prevailing practices without targeted interventions. This potentially led to a sustained or increased level of energy demand over time, driven by ongoing economic and population growth.

Conversely, the NDC scenario incorporated specific policies and actions designed to influence energy demand and achieve reduction targets. The outcome was likely to be a more controlled growth or even a reduction in energy demand compared to the BAU scenario, contingent on the effectiveness and stringency of implemented measures.

The Long-Term Strategy scenario envisioned a transformative approach toward energy demand, aligned with broader sustainability goals. Focused on achieving net-zero emissions, this scenario involved significant shifts in energy sources, increased energy efficiency, and the adoption of cleaner technologies. Consequently, a notable decrease or stabilization in energy demand was expected as the LTS sought to establish a more sustainable and environmentally friendly trajectory.

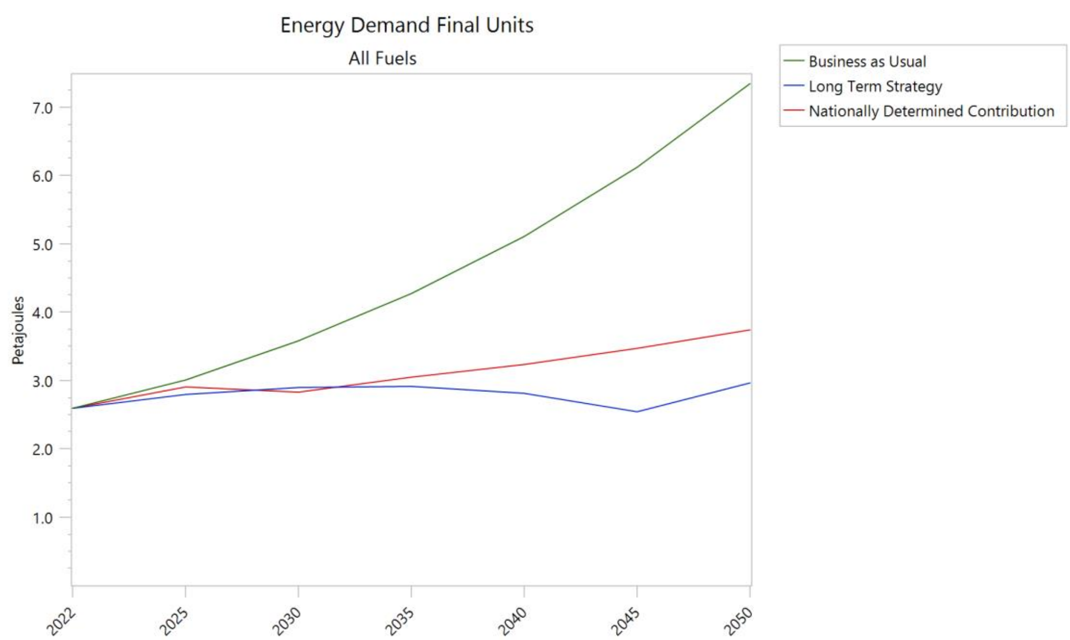


Figure 37 Energy demand comparison in all three scenarios

When comparing the Business as Usual (BAU) and Nationally Determined Contribution (NDC) scenarios, it became evident that the NDC scenario consistently exhibited lower energy demand throughout the forecasted years. The trajectory of energy demand pattern is shown in Figure 37. In 2025, there was a noteworthy 3.16% reduction in energy demand in the NDC scenario compared to BAU. This trend intensified over time, with reductions of 21.09%, 28.61%, 36.79%, 43.31%, and 49.00% in 2030, 2035, 2040, 2045, and 2050, respectively. These findings underscored the substantial impact of the NDC scenario in mitigating energy demand and, by extension, potential environmental implications.

Similarly, when assessing the contrast between BAU and Long-Term Strategy (LTS) scenarios, a consistent pattern emerged wherein the LTS scenario consistently predicted a decrease in energy demand compared to BAU. In 2025, the LTS scenario indicated a 6.99% reduction, followed by progressively larger reductions of 19.11%, 31.78%, 44.95%, 58.56%, and 59.61% in 2030, 2035, 2040, 2045, and 2050, respectively. These findings underscored the LTS scenario's efficacy in achieving substantial reductions in energy demand over the specified time horizon.

In summary, the NDC and LTS scenarios both exhibit a clear departure from the business-as-usual trajectory, demonstrating their potential to drive significant reductions in energy demand. While the NDC scenario consistently maintains a lower energy demand compared to BAU, the LTS scenario showcases an even more pronounced impact. These findings underscore the importance of adopting proactive measures, as outlined in the NDC and LTS scenarios, to achieve sustainable and resilient energy systems for the future.

4.13.2 Emission Forecast

Examining emissions across three scenarios: Business as Usual (BAU), Nationally Determined Contributions (NDC), and Long-Term Strategy (LTS), provided insights into their respective trajectories.

In the Business as Usual scenario, emissions were expected to follow historical patterns, representing a continuation of prevailing practices without targeted interventions. This potentially led to a sustained or increased level of emissions over time, driven by ongoing economic and population growth.

Contrastingly, the NDC scenario incorporated specific policies and actions designed to achieve emission reduction targets. The outcome was likely to be a more controlled growth or reduction in emissions compared to the BAU scenario, contingent on the effectiveness and stringency of implemented measures.

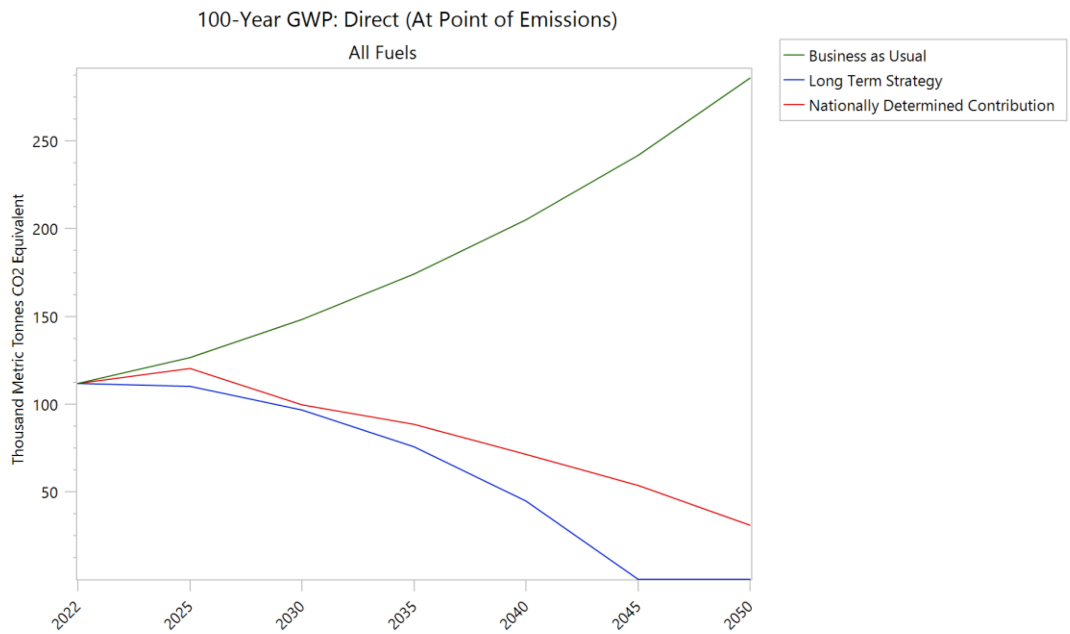


Figure 38 Emission forecast comparison in all three scenarios

The Long-Term Strategy scenario envisioned a transformative approach toward emissions, aligned with broader sustainability goals. Focusing on achieving net-zero emissions, this scenario involved significant shifts in energy sources, technology adoption, and overall emission reduction strategies. Consequently, a notable decrease or stabilization in emissions was expected as the LTS sought to establish a more sustainable and environmentally friendly trajectory.

Firstly, a comparison between the BAU and NDC scenarios demonstrated a consistent and substantial reduction in emissions within the NDC framework. In 2025, emissions in the NDC scenario were 4.9% less than BAU, marking an initial departure from the business-as-usual trajectory. This trend intensified over the forecasted years, with increasingly substantial reductions of 32.8%, 49.3%, 65.81%, 77.9%, and 89.2% in 2030, 2035, 2040, 2045, and 2050, respectively. These findings underscored the effectiveness of the NDC scenario in curbing emissions and aligning with environmentally conscious goals. The trajectory of energy demand pattern is shown in Figure 38.

Similarly, when evaluating the contrast between BAU and LTS scenarios, a consistent pattern emerged wherein the LTS scenario consistently predicted a remarkable reduction in emissions compared to the business-as-usual trajectory. In 2025, the LTS scenario indicated a 13.0% reduction, followed by progressively larger reductions of 34.8%, 56.5%, 78.3%, and 100% in 2030, 2035, 2040, and 2045, respectively. These findings highlighted the potency of the LTS scenario in achieving substantial and, in the case of 2045, complete emissions reduction, showcasing a clear departure from conventional emission pathways.

In summary, both the NDC and LTS scenarios exhibited a significant departure from the emissions trajectory outlined in the business-as-usual scenario. While the NDC scenario consistently demonstrated noteworthy reductions, the LTS scenario went even further, presenting a compelling case for adopting strategic and forward-thinking measures to achieve substantial emissions reductions and contribute to a more sustainable and resilient future.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

According to various reports from DOTM, ADB, and utilizing the Krejcie Morgan's formula to determine a representative sample, it is estimated that there are 153,194 vehicles registered in Sudurpaschim province, out of which around 115,024 are currently operating in Sudurpaschim Province. The study presents several scenarios to analyze the energy consumption and greenhouse gas (GHG) emissions in the transport sector of the Sudurpaschim province. In the base year, it is estimated that the total energy consumption in the area is 2.59 PJ, with petrol accounting for 43.2 %, diesel for 53.8%, and electricity for 3.0% of the energy consumed. Among the different modes of transportation, two wheeler consume 37.59% of the total energy, followed by bus at 21.36%, tractor and power tiller at 18.48%, truck at 7.82%, car at 5.02%, and auto rickshaw at 4.45%, e rickshaw at 2.95% and jeep at 3.33%. The GHG emissions amount to 117.67 thousand MT of CO_2eq predominantly consisting of CO_2 emissions. (106.23 thousand MT of CO_2eq). In the final year of projection.

- Under the business-as-usual (BAU) scenario, which assumes the continuation of current energy consumption patterns, it is projected that the energy consumption in the transport sector of Sudurpaschim province will increase to 4.27 PJ by 2030 and 7.34 PJ by 2050 with a CAGR of 3.78%. Two wheelers are expected to be the major consumers, accounting for 1.42 PJ in 2030 and 3.13 PJ in 2050. In 2030, diesel is expected to contribute 45.52% of the total energy consumption, followed by petrol at 45.52%, and electricity at 3.15% each. By 2050, petrol is projected to contribute 48.22%, diesel 48.44%, electricity will each account for 3.33% of the total energy consumed in the transportation sector. The GHG emissions in this scenario are projected to reach 148.22 thousand metric tonnes by 2030 and 258.78 thousand metric tonnes by 2050 with a CAGR of 3.42%.
- In the Nationally Determined Contribution (NDC) scenario, aligned with the implications of the Sustainable Development Goals (SDGs), energy consumption is expected to reach 2.82 PJ by 2030 and 3.74 PJ by 2050 increasing at a CAGR of 1.32%. In 2030, diesel is anticipated to contribute 53.60% of the total energy

consumption in the transport sector, followed by petrol at 41.04%, electricity at 5.36%. By 2050, the energy mix is expected to consist of 61.16% electricity, 15.38% petrol, 10.94% diesel and 12.53% green hydrogen. The GHG emissions in this scenario are projected to reach 99.61 thousand metric tonnes by 2030 and 30.81 thousand metric tonnes by 2050 declining at a CAGR of 4.49%.

- Finally in the Long Term Strategy (LTS) scenario, aligned with the implications for Net-Zero Emission (NZE), the energy consumption in the transport sector of Sudurpaschim province is expected to reach 2.89 PJ by 2030 and decrease to 2.96 PJ by 2050 at a CAGR of 0.48%. In 2030, diesel is projected to contribute 41.39% of the total energy consumption, followed by petrol at 36.71%, electricity at 18.15% and hydrogen fuel at 3.75%. By 2050, electricity is expected to contribute 84.17% of the total energy consumption, with hydrogen fuel accounting for the remaining 15.83%. The GHG emissions in this scenario are projected to reach 96.66 thousand metric tonnes by 2030 and decline at a rate of 4.49% till 2040 achieve net-zero emissions by 2045.
- Comparing BAU and NDC scenarios in terms of energy demand, in 2025, there was a noteworthy 3.16% reduction in energy demand in the NDC scenario compared to BAU. This trend intensified over time, with reductions of 21.09%, 28.61%, 36.79%, 43.31%, and 49.00% in 2030, 2035, 2040, 2045, and 2050, respectively. When assessing the contrast between BAU and LTS scenarios, a consistent pattern emerges wherein the LTS scenario consistently predicts a decrease in energy demand compared to BAU. In 2025, the LTS scenario indicated a 6.99% reduction, followed by progressively larger reductions of 19.11%, 31.78%, 44.95%, 58.56%, and 59.61% in 2030, 2035, 2040, 2045, and 2050, respectively.
- Comparing BAU and NDC scenarios in terms of emission forecast, in 2025, emissions in the NDC scenario were 4.9% less than BAU, marking an initial departure from the business-as-usual trajectory. This trend intensified over the forecasted years, with increasingly substantial reductions of 32.8%, 49.3%, 65.81%, 77.9%, and 89.2% in 2030, 2035, 2040, 2045, and 2050, respectively. Similarly, when evaluating the contrast between BAU and LTS scenarios, a consistent pattern emerged wherein the LTS scenario consistently predicted a

remarkable reduction in emissions compared to the business-as-usual trajectory. In 2025, the LTS scenario indicated a 13.0% reduction, followed by progressively larger reductions of 34.8%, 56.5%, 78.3%, and 100% in 2030, 2035, 2040, and 2045, respectively.

The analysis of energy demand and emission forecast scenarios for Sudurpaschim province underscores the intricate interplay between policy interventions and the broader economic and societal landscape. While nationally determined contributions and long-term strategies provide a structured framework for shaping future energy trajectories, a comprehensive understanding necessitates the inclusion of economic parameters. The often-overlooked factors, such as the life standards of the population and their preferences in transportation modes, play pivotal roles in shaping realistic outcomes. Therefore, future forecasting efforts may go for a more holistic approach, acknowledging the dynamic nature of societal preferences and economic conditions. To enhance the accuracy and relevance of energy forecasts, policymakers are encouraged to incorporate a diverse range of factors, fostering a nuanced understanding that goes beyond policy papers and embraces the multifaceted nature of our evolving energy landscape. The limitations of this study are rooted in its heavy reliance on policy papers that Nepal has committed to in the international forum. While the approach based on these policy papers may seem optimistic, achieving a more realistic understanding necessitates the consideration of factors beyond gross value added and population growth. Economic prosperity and people's choices play crucial roles in shaping energy demand and emissions, and this study recognizes the need for a more comprehensive exploration of these additional factors. Therefore, it should not be solely relied upon as the definitive document for the preparation of energy demand and emission forecasts. Based on the study findings, it is recommended that Sudurpaschim Province proactively promotes electric mobility initiatives and invests in infrastructure from the outset of its development. Given the region's early development stage, prioritizing renewable energy choices aligns with the country's international commitments and can contribute to a cleaner, more environmentally conscious development path.

REFERENCES

Andrew I. Kay, R. B. (2014). Achieving reductions in greenhouse gases in the US road transportation sector. *Energy Policy*, 536-545.

Bajracharya, I., & Bhattrai, N. (2016). Road Transportation Energy Demand and Environmental Emission: A Case of Kathmandu Valley. *Hydro Nepal Journal of Water Energy and Environment*, 8-9.

BP Statistical . (2019). *BP Statistical Review of World Energy*. BP Statistical .

Clean Energy Nepal. (2014). *Environment Friendly Vehicle Transport Policy*. Retrieved from Clean Energy Nepal: https://www.cen.org.np/clean-air-and-urban-mobility/fuel-economy-labelling-and-emobility-promotion-in-nepal.html#:~:text=Environment%2Dfriendly%20Vehicle%20and%20Transport,environment%2Dfriendly%20vehicles%20by%202020.

Dhiraj, G., Venkatappa, K., & Adhikary, P. (2008). The Influence of Meteorological Conditions on PM10 Concentrations in Kathmandu Valley. *International Journal of Environmental Research*.

Dhital, H. C., & Shakya, S. (2014). Implication of Sustainable Low Carbon Transportation Development Strategy in Emerging City: A case of Kathmandu Valley. *IOE Graduate Conference*, (p. 223). Kathmandu.

Dhital, H. C., & Shakya, S. (2014). Implication of Sustainable Low Carbon Transportation Development Strategy in Emerging City: A case of Kathmandu Valley. *IOE Graduate Conference*, (p. 10). Kathmandu.

GGGI. (2018). *National Action Plan for Electric Mobility*. Government of Nepal.

Ghimire, K. P., & Shrestha, S. R. (2014). Estimating Vehicular EMission in Kathmandu Valley , Nepal. *International Journal of Environment*, 142-143.

Government of Nepal. (2020). *Second Nationally Determined Contribution.*

Hempel, S. (2020). *Conducting Your Literature Review*. Washington, DC: American Psychological Association.

IEA. (2018). *Transport Sector CO2 Emissions*. Retrieved from IEA: https://www.iea.org/data-and-statistics/charts/transport-sector-co2-emissions-by-mode-in-the-sustainable-development-scenario-2000-2030

IEA. (2020). *World Energy Balances.*

IEA. (2022, July). *Transport*. Retrieved from IEA: https://www.iea.org/topics/transport

Malla, S. (2014). Assessment of mobility and its impact on energy use and air pollution. 12.

MOEWRI. (2019). *National Energy Efficiency Strategy, 2075.* Kathmandu: MOEWRI.

MoF. (2022). *Economic Survey 2022.* Kathamandu: Ministry of Finance.

MoFE. (2021). *Assessment of Electric Mobility Targets for Nepal's 2020 Nationally Determined Contributions (NDC).* Government of Nepal.

NASA. (2022, July 11). *Global Cliamte Change*. Retrieved from NASA: https://climate.nasa.gov/news/2915/the-atmosphere-getting-a-handle-on-carbon-dioxide/#:~:text=The%20concentration%20of%20carbon%20dioxide,it%20was%20near%20370%20ppm.

Nepal Oil Corporation. (2021). *Import And Sales*. Retrieved from Nepal Oil Corporation Limited: http://noc.org.np/import

NPC. (2017). *Nepal Sustainable Development Goals Status and Roadmap 2016- 2030.* Kathmandu: National Planning Commission, GoN.

NPC. (2019). *The Fifteenth Plan (Fiscal Year 2019/20 – 2023/24).* Kathmandu: National Planning Commission, GoN.

OEC. (2021). *Refined Petroleum in Nepal*. Retrieved from OEC: https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/npl

Rivera Gonzalez, L. B. (2020). Long-Term Forecast of Energy and Fuels Demand Towards a Sustainable Road Transport Sector in Ecuador (2016–2035): A LEAP Model Application. *Sustainability*, 26.

Sharma, A., & Roychowdhury, A. (1996). *Slow Murder : The Deadly Story of Vehicular Pollution in India.* New Delhi: Centre for Science and Environment,.

Sharma, B., & Shrestha, A. (2023). Petroleum dependence in developing countries with an emphasis on Nepal and potential keys. *Energy Strategy Reviews*.

Shrestha, R. M., & Rajbhandari, S. (2010). Energy and Environmental Implications of Carbon Emission Reduction Targets: A case study of Kathmandu , Nepal. *Energy Policy*.

State of Global Air. (2020). *Global Health Impacts of Air Pollution*. Retrieved from State of Global Air: https://www.stateofglobalair.org/health/global

Teske, D., Niklas, D., & Miyake, D. (2023). *Technical Scenario for 100% Renewable Energy in Nepal by 2050.* Institute for Sustainable Futures (ISF).

UNFCCC. (2021). Nepal - High-level Segment Statement COP 26. *COP 26* (p. 2). Glasgow: UNFCCC.

UNFCCC. (2021). *Nepal's Longterm Strategy for Net Zero Emissions.*

United Nation Environment Programme. (2013). *Atmospheric Brown Clouds: Emission Inventory Manual.* United Nation Environment Programme.

United Nations. (2023). *Sustainable Development*. Retrieved from United Nations: https://sdgs.un.org/goals

United Nations Environment Programme, Asian Institute of Technology, & Institute for Advanced Sustainability Studies. (2013). *Atmospheric Brown Clouds: Emission Inventory Manual.*

WECS. (2010). *WECS.*

WECS. (2022). *Energy Sector Synopsis Report 2021/2022.* Government of Nepal.

Xiaojun Hu, S. C. (2010). Energy for sustainable road transportation in China: Challenges, initiatives and policy implications,. *Energy*, 4289-4301.

ANNEX I

Energy Demand Final Units								
Scenario: Business as Usual, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.28	2.78	3.39	4.13	5.03	6.14	25.66
Freight	0.68	0.72	0.80	0.89	0.98	1.09	1.20	6.37
Total	2.59	3.00	3.58	4.27	5.11	6.12	7.34	32.02

Energy Demand Final Units								
Scenario: Nationally Determined Contribution, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.18	2.02	2.15	2.22	2.34	2.48	15.29
Freight	0.68	0.72	0.81	0.91	1.01	1.13	1.27	6.53
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Energy Demand Final Units								
Scenario: Long Term Strategy, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.06	2.08	2.00	1.79	1.39	1.70	12.94
Freight	0.68	0.73	0.82	0.91	1.02	1.14	1.27	6.57
Total	2.59	2.79	2.89	2.92	2.81	2.54	2.96	19.51

Energy Demand Final Units								
Scenario: Business as Usual								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	0.11	0.13	0.16	0.19	0.23	0.28	0.34	1.43
Private	1.79	2.05	2.42	2.86	3.39	4.02	4.79	21.32
Public	0.69	0.82	1.00	1.22	1.49	1.82	2.22	9.27
Total	2.59	3.00	3.58	4.27	5.11	6.12	7.34	32.02

Energy Demand Final Units								
Scenario: Nationally Determined Contribution								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	0.11	0.13	0.12	0.13	0.13	0.14	0.16	0.92
Private	1.79	1.98	1.87	1.97	2.02	2.08	2.14	13.86
Public	0.69	0.80	0.84	0.95	1.08	1.24	1.44	7.05
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Energy Demand Final Units								
Scenario: Long Term Strategy, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
Private	1.8	1.9	1.9	1.9	1.7	1.4	1.5	12.1
Public	0.7	0.8	0.9	0.9	1.0	1.1	1.3	6.6
Total	2.6	2.8	2.9	2.9	2.8	2.5	3.0	19.5

Energy Demand Final Units								
Scenario: Business as Usual								
Branch: Demand\Transport								
Units: Petajoules								
Fuel	2022	2025	2030	2035	2040	2045	2050	Total
Electricity	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.04
Gasoline	1.12	1.34	1.63	1.99	2.42	2.95	3.60	15.05
Diesel	1.40	1.57	1.84	2.15	2.52	2.97	3.49	15.94
Hydrogen	-	-	-	-	-	-	-	-
Total	2.6	3.0	3.6	4.3	5.1	6.1	7.3	32.0

Energy Demand Final Units								
Scenario: Nationally Determined Contribution								
Branch: Demand\Transport								
Units: Petajoules								
Fuel	2022	2025	2030	2035	2040	2045	2050	Total
Electricity	0.1	0.2	0.5	0.8	1.3	1.7	2.3	6.8
Gasoline	1.1	1.2	1.0	0.9	0.8	0.7	0.6	6.3
Diesel	1.4	1.6	1.3	1.2	0.9	0.7	0.4	7.4
Hydrogen	-	-	0.1	0.1	0.2	0.3	0.5	1.2
Total	2.6	2.9	2.8	3.1	3.2	3.5	3.7	21.8

Energy Demand Final Units								
Scenario: Long Term Strategy								
Branch: Demand\Transport								
Units: Petajoules								
Fuel	2022	2025	2030	2035	2040	2045	2050	Total
Electricity	0.08	0.23	0.53	0.92	1.44	2.11	2.50	7.80
Gasoline	1.12	1.16	1.06	0.86	0.53	-	-	4.74
Diesel	1.40	1.37	1.20	0.93	0.55	-	-	5.45
Hydrogen	-	0.04	0.11	0.20	0.30	0.42	0.47	1.53
Total	2.59	2.79	2.89	2.92	2.81	2.54	2.96	19.51

Energy Demand Final Units								
Scenario: Business as Usual								
Demand: Transport								
Units: Petajoules (PJ)								
Vehicle type	2022	2025	2030	2035	2040	2045	2050	Total
Auto ricksaw	0.12	0.14	0.17	0.20	0.25	0.30	0.37	1.55
Bus	0.55	0.66	0.81	0.98	1.20	1.46	1.78	7.44
Car	0.13	0.16	0.19	0.23	0.28	0.34	0.42	1.75
E ricksaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Jeep	0.06	0.07	0.09	0.11	0.13	0.16	0.19	0.81
Tractor Powerr Tiller	0.48	0.51	0.56	0.62	0.69	0.76	0.85	4.47
Truck Crane Doze	0.20	0.22	0.24	0.26	0.29	0.32	0.36	1.89
Two wheeler	0.98	1.16	1.42	1.73	2.11	2.57	3.13	13.08
Total	2.59	3.00	3.58	4.27	5.11	6.12	7.34	32.02

Energy Demand Final Units								
Scenario: Nationally Determined Contribution (NDC)								
Demand:Transport								
Units: Petajoules								
Vehicle type	2022	2025	2030	2035	2040	2045	2050	Total
Auto ricksaw	0.12	0.13	0.15	0.17	0.21	0.25	0.31	1.34
Bus	0.55	0.64	0.64	0.71	0.79	0.88	0.99	5.20
Car	0.13	0.15	0.14	0.14	0.14	0.15	0.15	0.99
E ricksaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Jeep	0.06	0.07	0.07	0.08	0.08	0.09	0.10	0.55
Tractor Powerr Tiller	0.48	0.51	0.57	0.64	0.71	0.80	0.89	4.59
Truck Crane Dozer	0.20	0.22	0.24	0.27	0.30	0.34	0.38	1.94
Two wheeler	0.98	1.10	0.91	0.90	0.84	0.77	0.69	6.18
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Energy Demand Final Units								
Scenario: Long Term Strategy								
Demand: Transport								
Units: Petajoules								
Vehicle type	2022	2025	2030	2035	2040	2045	2050	Total
Auto rickshaw	0.12	0.13	0.16	0.18	0.22	0.25	0.31	1.36
Bus	0.55	0.61	0.65	0.68	0.69	0.67	0.82	4.68
Car	0.13	0.14	0.14	0.13	0.11	0.08	0.09	0.82
E rickshaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Jeep	0.06	0.07	0.07	0.07	0.07	0.06	0.08	0.48
Tractor Power Tiller	0.48	0.51	0.57	0.64	0.72	0.80	0.89	4.62
Truck Crane Dozer	0.20	0.22	0.24	0.27	0.30	0.34	0.38	1.95
Two wheeler	0.98	1.02	0.95	0.80	0.54	0.13	0.16	4.57
Total	2.59	2.79	2.89	2.92	2.81	2.54	2.96	19.51

Energy Demand Final Units								
Scenario: Business as Usual, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.28	2.78	3.39	4.13	5.03	6.14	25.66
Private	1.12	1.34	1.63	1.99	2.42	2.95	3.60	15.05
Public	0.69	0.82	1.00	1.22	1.49	1.82	2.22	9.27
Institutional	0.10	0.12	0.14	0.18	0.21	0.26	0.32	1.33
Freight	0.68	0.72	0.80	0.89	0.98	1.09	1.20	6.37
Private	0.67	0.71	0.79	0.87	0.97	1.07	1.18	6.26
Institutional	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.10
Total	2.59	3.00	3.58	4.27	5.11	6.12	7.34	32.02

Energy Demand Final Units								
Scenario: Nationally Determined Contribution, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.18	2.02	2.15	2.22	2.34	2.48	15.29
Private	1.12	1.27	1.07	1.08	1.02	0.97	0.90	7.43
Public	0.69	0.80	0.84	0.95	1.08	1.24	1.44	7.05
Institutional	0.10	0.11	0.11	0.11	0.12	0.13	0.14	0.81
Freight	0.68	0.72	0.81	0.91	1.01	1.13	1.27	6.53
Private	0.67	0.71	0.80	0.89	1.00	1.11	1.25	6.43
Institutional	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.11
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Energy Demand Final Units								
Scenario: Nationally Determined Contribution, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.18	2.02	2.15	2.22	2.34	2.48	15.29
Private	1.12	1.27	1.07	1.08	1.02	0.97	0.90	7.43
Public	0.69	0.80	0.84	0.95	1.08	1.24	1.44	7.05
Institutional	0.10	0.11	0.11	0.11	0.12	0.13	0.14	0.81
Freight	0.68	0.72	0.81	0.91	1.01	1.13	1.27	6.53
Private	0.67	0.71	0.80	0.89	1.00	1.11	1.25	6.43
Institutional	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.11
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Energy Demand Final Units								
Scenario: Long Term Strategy, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.9	2.1	2.1	2.0	1.8	1.4	1.7	12.9
Private	1.1	1.2	1.1	1.0	0.7	0.2	0.3	5.6
Public	0.7	0.8	0.9	0.9	1.0	1.1	1.3	6.6
Institutional	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7
Freight	0.7	0.7	0.8	0.9	1.0	1.1	1.3	6.6
Private	0.7	0.7	0.8	0.9	1.0	1.1	1.2	6.5
Institutional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Total	2.6	2.8	2.9	2.9	2.8	2.5	3.0	19.5

Energy Demand Final Units								
All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Scenario	2022	2025	2030	2035	2040	2045	2050	Total
BAU	2.6	3.0	3.6	4.3	5.1	6.1	7.3	32.0
LTS	2.6	2.8	2.9	2.9	2.8	2.5	3.0	19.5
NDC	2.6	2.9	2.8	3.1	3.2	3.5	3.7	21.8
Total	7.8	8.7	9.3	10.2	11.2	12.1	14.0	73.4

Energy Demand Final Units								
Scenario: Business as Usual, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.9	2.3	2.8	3.4	4.1	5.0	6.1	25.7
Private	1.1	1.3	1.6	2.0	2.4	3.0	3.6	15.1
Two wheeler	1.0	1.1	1.4	1.7	2.1	2.5	3.1	12.8
Car	0.1	0.1	0.2	0.2	0.3	0.3	0.4	1.6
Jeep	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.7
Public	0.7	0.8	1.0	1.2	1.5	1.8	2.2	9.3
Bus	0.50	0.59	0.73	0.88	1.08	1.31	1.60	6.70
Auto ricksaw	0.12	0.14	0.17	0.20	0.25	0.30	0.37	1.55
E ricksaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Institutional	0.10	0.12	0.14	0.18	0.21	0.26	0.32	1.33
Car	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.16
Jeep	0.01	0.01	0.02	0.02	0.02	0.03	0.04	0.15
Bus	0.06	0.07	0.08	0.10	0.12	0.15	0.18	0.74
Two wheeler	0.02	0.02	0.03	0.04	0.04	0.05	0.07	0.28
Freight	0.68	0.72	0.80	0.89	0.98	1.09	1.20	6.37
Private	0.67	0.71	0.79	0.87	0.97	1.07	1.18	6.26
Truck Crane Doze	0.19	0.20	0.23	0.25	0.28	0.31	0.34	1.80
Tractor Powerr Tiller	0.48	0.51	0.56	0.62	0.69	0.76	0.84	4.46
Institutional	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.10
Truck Crane Doze	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.09
Tractor Powerr Tiller	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	2.59	3.00	3.58	4.27	5.11	6.12	7.34	32.02

Energy Demand Final Units								
Scenario: Nationally Determined Contribution, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.18	2.02	2.15	2.22	2.34	2.48	15.29
Private	1.12	1.27	1.07	1.08	1.02	0.97	0.90	7.43
Two wheeler	0.95	1.08	0.89	0.89	0.82	0.76	0.68	6.06
Car	0.12	0.14	0.12	0.13	0.13	0.14	0.14	0.92
Jeep	0.05	0.06	0.06	0.06	0.07	0.08	0.08	0.45
Public	0.69	0.80	0.84	0.95	1.08	1.24	1.44	7.05
Bus	0.50	0.57	0.58	0.64	0.71	0.79	0.89	4.68
Auto ricksaw	0.12	0.13	0.15	0.17	0.21	0.25	0.31	1.34
E ricksaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Institutional	0.10	0.11	0.11	0.11	0.12	0.13	0.14	0.81
Car	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
Jeep	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.10
Bus	0.06	0.06	0.06	0.07	0.08	0.09	0.10	0.52
Two wheeler	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.12
Freight	0.68	0.72	0.81	0.91	1.01	1.13	1.27	6.53
Private	0.67	0.71	0.80	0.89	1.00	1.11	1.25	6.43
Truck Crane Doze	0.19	0.20	0.23	0.26	0.29	0.32	0.36	1.85
Tractor Powerr Tiller	0.48	0.51	0.57	0.63	0.71	0.79	0.89	4.58
Institutional	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.11
Truck Crane Doze	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.09
Tractor Powerr Tiller	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	2.59	2.91	2.82	3.05	3.23	3.47	3.74	21.82

Energy Demand Final Units								
Scenario: Long Term Strategy, All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	1.91	2.06	2.08	2.00	1.79	1.39	1.70	12.94
Private	1.12	1.18	1.11	0.96	0.69	0.25	0.30	5.61
Two wheeler	0.95	1.00	0.93	0.78	0.53	0.13	0.15	4.47
Car	0.12	0.13	0.13	0.12	0.10	0.07	0.09	0.75
Jeep	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.39
Public	0.69	0.78	0.86	0.93	1.00	1.06	1.29	6.61
Bus	0.50	0.55	0.59	0.61	0.62	0.60	0.74	4.22
Auto ricksaw	0.12	0.13	0.16	0.18	0.22	0.25	0.31	1.36
E ricksaw	0.08	0.09	0.11	0.14	0.17	0.20	0.25	1.03
Institutional	0.10	0.11	0.11	0.11	0.10	0.09	0.11	0.73
Car	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
Jeep	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09
Bus	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.47
Two wheeler	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.10
Freight	0.68	0.73	0.82	0.91	1.02	1.14	1.27	6.57
Private	0.67	0.72	0.80	0.90	1.01	1.13	1.25	6.47
Truck Crane Doze	0.19	0.21	0.23	0.26	0.29	0.32	0.36	1.86
Tractor Powerr Tiller	0.48	0.51	0.57	0.64	0.72	0.80	0.89	4.60
Institutional	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.11
Truck Crane Doze	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.09
Tractor Powerr Tiller	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	2.59	2.79	2.89	2.92	2.81	2.54	2.96	19.51

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Business as Usual								
Demand:Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
GHG	2022	2025	2030	2035	2040	2045	2050	Total
Carbon Dioxide	106.23	120.09	140.55	164.86	193.80	228.31	269.53	1,223.36
Methane	3.11	3.69	4.49	5.46	6.64	8.07	9.82	41.29
Nitrous Oxide	2.32	2.68	3.18	3.78	4.51	5.38	6.43	28.28
Total	111.67	126.46	148.22	174.10	204.94	241.76	285.78	1,292.93

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Nationally Determined Contribution, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	5.77	6.37	4.83	4.57	3.97	3.40	2.46	31.37
Private	64.44	67.99	58.94	50.90	39.61	25.84	8.59	316.31
Public	41.45	45.88	35.84	32.80	27.85	24.29	19.77	227.87
Total	111.67	120.24	99.61	88.26	71.43	53.53	30.81	575.55

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Long Term Strategy, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	5.8	5.9	5.3	4.3	2.6	-	-	23.8
Private	64.4	61.2	52.2	39.7	22.7	-	-	240.2
Public	41.5	42.9	39.1	31.7	19.3	-	-	174.5
Total	111.7	110.0	96.7	75.7	44.6	-	-	438.5

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Business as Usual, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	5.77	6.76	8.14	9.80	11.82	14.26	17.22	73.78
Private	64.44	70.40	80.08	91.28	104.27	119.36	136.95	666.79
Public	41.45	49.30	59.99	73.01	88.85	108.14	131.61	552.36
Total	111.67	126.46	148.22	174.10	204.94	241.76	285.78	1,292.93

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Nationally Determined Contribution, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	5.77	6.37	4.83	4.57	3.97	3.40	2.46	31.37
Private	64.44	67.99	58.94	50.90	39.61	25.84	8.59	316.31
Public	41.45	45.88	35.84	32.80	27.85	24.29	19.77	227.87
Total	111.67	120.24	99.61	88.26	71.43	53.53	30.81	575.55

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Long Term Strategy, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Institutional	5.8	5.9	5.3	4.3	2.6	-	-	23.8
Private	64.4	61.2	52.2	39.7	22.7	-	-	240.2
Public	41.5	42.9	39.1	31.7	19.3	-	-	174.5
Total	111.7	110.0	96.7	75.7	44.6	-	-	438.5

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Business as Usual, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	63.26	75.27	91.63	111.55	135.80	165.33	201.29	844.15
Freight	48.41	51.19	56.58	62.55	69.14	76.43	84.49	448.78
Total	111.67	126.46	148.22	174.10	204.94	241.76	285.78	1,292.93

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Nationally Determined Contribution, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	63.26	68.94	54.07	50.48	43.60	38.22	30.81	349.38
Freight	48.41	51.30	45.54	37.78	27.83	15.31	-	226.17
Total	111.67	120.24	99.61	88.26	71.43	53.53	30.81	575.55

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
Scenario: Long Term Strategy, All Fuels, All GHGs								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Branch	2022	2025	2030	2035	2040	2045	2050	Total
Passenger	63.3	65.5	59.8	48.5	29.5	-	-	266.5
Freight	48.4	44.5	36.9	27.2	15.0	-	-	172.0
Total	111.7	110.0	96.7	75.7	44.6	-	-	438.5

Energy Demand Final Units								
All Fuels								
Branch: Demand\Transport								
Units: Petajoules								
Scenario	2022	2025	2030	2035	2040	2045	2050	Total
BAU	2.6	3.0	3.6	4.3	5.1	6.1	7.3	32.0
LTS	2.6	2.8	2.9	2.9	2.8	2.5	3.0	19.5
NDC	2.6	2.9	2.8	3.1	3.2	3.5	3.7	21.8
Total	7.8	8.7	9.3	10.2	11.2	12.1	14.0	73.4

Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands								
All Fuels								
Branch: Demand\Transport								
Units: Thousand Metric Tonnes CO2 Equivalent								
Scenario	2022	2025	2030	2035	2040	2045	2050	Total
BAU	111.7	126.5	148.2	174.1	204.9	241.8	285.8	1,292.9
LTS	111.7	110.0	96.7	75.7	44.6	-	-	438.5
NDC	111.7	120.2	99.6	88.3	71.4	53.5	30.8	575.6
Total	335.0	356.7	344.5	338.1	320.9	295.3	316.6	2,307.0

ANNEX II

प्रदूषण अध्ययन केन्द्र

पुल्चोक, ललितपुर

मिति:...........................

नेपालमा ई-वाहन प्रवर्द्धनका सम्भावनाहरूमा सर्वेक्षण प्रश्नावली

नेपालमा आन्तरिक दहन इन्जिन सवारी साधन (ICEVs)हरूबाट हुने हरितगृह ग्यास उत्सर्जन र विद्युतीय सवारी साधनहरू जस्ता विकल्पहरूतर्फ सर्ने उनीहरूको चासोको बारेमा प्रयोगकर्ताको दृष्टिकोण अध्ययन गर्नको लागि प्रश्नावली।

इमेल ....

उत्तरदाता र स्थान बारे सामान्य जानकारी

हामी यो डाटा अनुसन्धान उद्देश्यको लागि मात्र प्रयोग गर्न प्रतिबद्ध छौं। हामी तपाईंलाई आश्वासन दिन्छौं कि साझा गरिएका सबै जानकारीहरू गोपनीयताका साथ र नैतिक दिशानिर्देशहरू र डेटा सुरक्षा नियमहरूको अनुपालनमा व्यवहार गरिनेछ। यस जानकारीले नेपालका सबै प्रदेश र जिल्लाका प्रयोगकर्ताहरूलाई समेट्ने विविध डाटाबेस सिर्जना गर्न मद्दत गर्नेछ।

१. पूरा नाम: ....

२. सम्पर्क नम्बर: ....

३. उमेर: ....

४. लिङ्ग: ☐ पुरुष ☐ महिला ☐ अन्य: ....

५. प्रदेश: ....

६. नगरपालिका/गाउँपालिका: ....

७. वडा नम्बर: ....

८. औसत मासिक आय ☐ 20k ☐ 20-40k ☐ 40-70k ☐ 70k- 1L ☐ 1L माथि

सवारी साधनको सामान्य जानकारी

९. सवारी साधन मालिकको पुरा नाम: ....

१०. मालिकको सम्पर्क नम्बर: ....

११. सवारी साधनको नम्बर प्लेट: ....

१२. सवारी साधनको मोडेल: ....

१३. सवारी साधनको स्वामित्वको प्रकार

☐ व्यक्तिगत ☐ संस्थागत (निजी कर्पोरेट/सरकारी/दूतावास)

☐ सार्वजनिक (स्थानीय/छोटो दूरी) ☐ सार्वजनिक (लामो दूरी) ☐ ढुवानी

१४. सवारी साधन प्रयोग उद्देश्य:

☐ यात्रुवाहक गाडी (मानिसहरूलाई ढुवानी गर्न प्रयोग गरिन्छ। उदाहरण: कार, माइक्रोबस , बसहरू)

☐ मालवाहक गाडी (सामान वा कार्गोको ढुवानी। उदाहरण: ट्रकहरू, कार्गो भ्यानहरू, पिकअप ट्रकहरू)

१५. प्रयोग गरिएको इन्धनको प्रकार ☐ पेट्रोल ☐ डिजेल ☐ LP ग्यास

☐ बिजुली ☐ हाइड्रोजन ईन्धन ☐ जैव ईन्धन

☐ अन्य: ....

१६. इन्जिन क्षमता (IC इन्जिनको लागि CC / EV को लागि वाट): ....

१७. सवारी साधन क्षमता: ....

यात्रुवाहक सवारी साधनका लागि यात्रु संख्यामा र मालवाहक सवारी साधनको टनमा उदाहरण: मोटरसाइकलका लागि साधन क्षमता= २

सवारी साधन सञ्चालन

१८. आज सम्म यात्रा गरेको दूरी (किमि): ....

१९. खरिद मिति: ....

२०. वार्षिक मर्मत लागत- (औषत रु)): ....

२१. वर्षमा कति दिन सवारी साधान प्रयोग गर्नु हुन्छ? : ....

२२. एक दिनमा कति दुरीको यात्रा गर्नुहुन्छ? (किमि): ....

२३. एक दिनमा कति पटक यात्रा गर्नुहुन्छ? : ....

२४. एक यात्रामा यात्रुहरूको औसत संख्या: ....

२५. एक यात्रामा सवारीले बोक्ने औशत भार (kg/ ton): ....

(यात्रुवाहक सवारीका लागि केजीमा र मालवाहक सवारीका लागि टनमा)-

२६. सवारी संचालनको पिक समय

☐ 4:00 AM-8:00 AM ☐ 8:00 AM-12:00 PM ☐ 12:00 PM-4:00 PM

☐ 4:00 PM-8:00 PM ☐ 8:00 PM-12:00 PM ☐ अन्य:

२७. तपाईंले आफ्नो गाडी कति वर्षमा परिवर्तन गर्नुभएको छ वा भविष्यमा यसलाई परिवर्तन गर्ने योजना छ?

(कृपया वर्षहरूमा निर्दिष्ट गर्नुहोस्।): ....

ऊर्जा खपत

२८. सवारी साधनको प्रकार

☐ आन्तरिक दहन इन्जिन सवारी साधन (ICEVs): पेट्रोल / डिजेल प्रयोग गर्ने

☐ विद्युतीय सवारी साधन (EVs): बिजुलीको प्रयोगद्वारा चल्ने

☐ अन्य: ....

यदि तपाईंसँग IC इन्जिन सवारी साधन छ भने

२९. गाडीको माइलेज (किमि/लिटर): ....

३०. एक पटकमा कति मात्रामा इन्धनको भर्नुहुन्छ (लिटर): ....

३१. एक महिनामा कति पटक इन्धन भर्नुहुन्छ?: ....

३२.पेट्रोलियम पदार्थको लगातार बढ्दो मूल्य बारे तपाईको धारणा के छ?
....
....

यदि तपाईंसँग विद्युतीय सवारी साधन छ भने

३३. ब्याट्री प्रकार:	☐ लीड एसिड ब्याट्री	☐ निकल मेटल हाइड्राइड (NiMH) ब्याट्री
	☐ लिथियम-आयन (ली-आयन) ब्याट्री	☐ अन्य: ....

३४. ब्याट्रीको क्षमता (वाट): ....

३५. पूर्ण चार्ज पछि दिने माइलेज: ....

३६. पूर्ण चार्ज हुने लाग्ने समय: ....

३७. एक दिनमा पटक चार्ज गर्नुपर्छ: ....

३८. प्रति वर्ष मर्मतसम्भार गर्न लाग्ने खर्च (रू): ....

बाधा र अवरोधहरू

भविष्यमा विद्युतीय सवारी साधन प्रयोग गर्ने तपाईंको इच्छा। नयाँ गाडी किन्न जाँदै हुनुहुन्छ भने विद्युतीय सवारीमा लगानी गर्न इच्छुक हुनुहुन्छ?

३९. के तपाईं सवारीको लागि नयाँ प्रविधिहरू अपनाउन इच्छुक हुनुहुन्छ?

□ छु □ छैन

विद्युतीय अपनाउन का लागि प्रेरणा?

४०. सवारीलागि तपाईंद्वारा रुचाइएको मोड

□ इलेक्ट्रिक मोटरसाइकल □ इलेक्ट्रिक कार □ इलेक्ट्रिक बस

□ इलेक्ट्रिक टेम्पो □ अन्य: ....

४१. तपाईलाई कस्तो प्रकारको चार्जिङ स्टेशन उपयुक्त हुनेछ जस्तो लाग्छ? कृपया आफ्नो प्राथमिकता अनुसार क्रमबद्ध गर्नुहोस्।

S.N	तपाईंको निवासमा	पार्किङ स्थलमा	संस्थाहरूमा	चार्जिङ स्टेशनहरूका लागि छुट्टै क्षेत्र छुट्याएर
१				
२				
३				
४				

विद्युतीय सवारी साधन नअपनाउनु कारणहरू

४२. नअपनाउनु नहुनुको कारण?

□ विद्युतीय गाडी अझै परीक्षणको चरणमा छ □ विद्युतीय सवारीसाधन चार्ज गर्ने विकल्पको अभाव

□ नयाँ प्रविधिहरू महँगो छन् □ बजारमा उपलब्ध विकल्पको अभाव

□ बजारमा स्पेयर पार्ट्स / मर्मतको अभाव □ बिजुलीको लागत उच्च छ

□ अन्य: ....

४३. समग्रमा लागतको हिसाबले तपाईंलाई निम्न मध्ये कुन वाहन विकल्पहरू सामान्यतया सस्तो लाग्छ?

□ विद्युतीय सवारी साधन (EVs): बिजुलीको प्रयोगद्वारा चल्ने

□ आन्तरिक दहन इन्जिन सवारी साधन (ICEVs): पेट्रोल / डिजेल प्रयोगद्वारा चल्ने

□ अन्य:....................................

तपाईंको प्रतिक्रियाको लागि धन्यवाद!

Survey Questionnaire on Prospects of E-Vehicle Promotion in Nepal

A close end questionnaire to study user's viewpoint on Greenhouse Gases Emissions from IC Engine vehicles in Nepal and their interest on shifting toward greener mobility options like Electric Vehicles.

Email …………………………………………………….

GENERAL INFORMATION ABOUT RESPONDENT AND LOCATION

We are committed to using this data solely for research purpose. We assure you that all information shared will be treated with confidentiality and in compliance with ethical guidelines and data protection regulations. This information will assist in creating a diverse database covering the users from all the provinces and districts of Nepal.

1. Full Name: ……………………………………………………..……………..
2. Contact No. : ……………………………………………………..……………
3. Age: ………………………………………………………..……………………
4. Gender: ☐ Male ☐ Female ☐ Other: …………….
5. Province: ……………………………………………………………………..
6. Municipality/Rural Municipality: …………………………………………
7. Ward No.: ……………………………………………………………………..
8. Average Monthly Income
   ☐ Below 20 ☒ 20-40k ☐ 40-70k ☐ 70k- 1L ☐ Above 1L

GENERAL INFORMATION OF THE VEHICLE

9. Owner of the vehicle: ………………………………………………
10. Contact number of the owner: ……………………………………
11. Vehicle Number Plate: ………………………………………………
12. Vehicle Model: ……………………………………………………
13. Vehicle ownership type
    - ☐ Personal
    - ☐ Institutional (private corporate/government/embassy)
    - ☐ Public (local/short distance)
    - ☐ Public (long distance)
    - ☐ Freight
14. Vehicle Use Purpose :
    ☐ Passenger Vehicle ☐ Freight Vehicle

    Passenger Vehicle: Used to transport people. Example: Cars, SUVs, minivans, and buses
    Freight Vehicle: transport of goods or cargo. Example: Trucks, semi-trucks, cargo vans, pickup trucks

15. Type of Fuel used
    ☐ Petrol ☐ Diesel ☐ LP gas
    ☐ Electricity ☐ Hydrogen Fuel ☐ Biofuel
    ☐ Other: ……………………………………………………………….
16. Engine capacity *(CC for IC engine / Watt for EV)*: ……………………………..
17. Vehicle capacity: ……………………………………………………….
    *(In terms of **no. of passengers for passenger vehicles** and in **tons for freight vehicles**)*

VEHICLE OPERATION

18. Distance travelled till date (km): …………………......................
19. Purchase date: ……………………………………………………
20. Annual maintenance cost (NRs.): ………………………………..
    (Provide a tentative round figure)
21. Vehicle operating days in a year (day/year): …………………….
22. Distance travelled per day (km): …………………………………
23. No. of trips per day: ……………………………………………
24. Average number of passengers per trip: ………………………….
25. Average load carried per trip: …………………………………….
    (In kg for passenger vehicle and in tons for freight vehicles)
26. Peak operation time

    ☐ 4:00 AM-8:00 AM ☐ 8:00 AM-12:00 PM ☐ 12:00 PM-4:00 PM

    ☐ 4:00 PM-8:00 PM ☐ 8:00 PM-12:00 PM ☐ Other:

27. How often have you changed your vehicle or plan to change it in the future?
    (Please specify in years.): ……………………………………...........................

ENERGY CONSUMPTION

28. Type of Vehicle

    ☐ IC Engine Vehicle ☐ Electric Vehicle ☐ Other: ………….

If you own an IC engine vehicle

29. Vehicle mileage (km/l): ……………………………………...……………...
30. Quantity of Fuel filled at a time (liter): ……………………………………...
31. Frequency of Fuel Filling (per month): ……………………………………...
32. What is your opinion on constantly increasing price of petroleum
    products? ……………………………………………………………………………

……………………………………………………………………………………………
……………………………………………………………………………………………

If you own an Electric vehicle

33. Battery type:

☐ Lead-acid battery ☐ Nickel metal hydride (NiMH) battery

☐ Lithium-ion (Li-ion) battery ☐ Other: …………………….

34. Capacity of battery (Watt): ……………………………………….............
35. Mileage of full charge: ……………………………………....................
36. Time for full charging: ……………………………………….................
37. Charge per day: ……………………………………….............................
38. Maintenance per year (NRs): ………………………………………..........

BARRIERS AND CONSTRAINTS

Your willingness to use electric vehicles in the future. Are you willing to invest on electric vehicle if you are going to buy a new vehicle?

39. Are you interested in switching to any new technologies?

☐ Yes ☐ No

Motivation in shifting towards electric vehicle?

40. Preferred mode of Mobility

☐ Electric motorbike ☐ Electric car ☐ Electric bus

☐ Electric tempo ☐ Other: ………………………..

41. What type of charging station do you think will be suitable? Please rank in order of your preference.

S.N	At your Residence	At Parking lots	At Institutions	Allot separate areas for charging stations
1				
2				
3				
4				

REASONS FOR NOT SHIFITING

42. Reason for not shifting?

☐ Electric vehicle is still in testing phase
☐ Lack of options for charging the electric vehicle
☐ Newer technologies are expensive
☐ Lack of option available in market
☐ Lack of spare parts/ repairs in the market
☐ Electricity cost is high
☐ Other: ……………………………………………………………………….

43. Which one of the following vehicle options do you think is generally cheaper in terms of overall cost of acquisition?

☐ Electric Vehicles (EVs)
☐ Conventional Internal Combustion Engine Vehicles (ICEVs)
☐ Other:

THANK YOU FOR YOUR RESPONSE!

त्रिभुवन विश्वविद्यालय
Tribhuvan University
इन्जिनियरिङ अध्ययन संस्थान
Institute of Engineering

डीनको कार्यालय
OFFICE OF THE DEAN

GPO box- 1915, Pulchowk, Lalitpur
Tel: 977-5-521531, Fax: 977-5-525830
dean@ioe.edu.np, www.ioe.edu.np
गोश्वारा पो.ब. न- १९१५, पुल्चोक, ललितपुर
फोन- ५५२१५३१, फ्याक्स- ५५२५८३०

Date: November 26, 2023

To Whom It May Concern:

This is to certify that the paper titled "***Energy Demand Modelling and Emission Forecasting: A case study of Sudurpaschim Province***" (Submission# **626**) submitted by **Suraksha Pal** as the first author has been accepted after the peer-review process for presentation in the 14th IOE Graduate Conference being held during Nov 29 to Dec 1, 2023. Kindly note that the publication of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon the author's presence for presentation during the conference and timely response to further edits during the publication process.

Bhim Kumar Dahal, PhD
Convener,
14th IOE Graduate Conference

Energy Demand Modelling and Emission Forecasting for the Penetration of E-mobility in Sudurpaschim Province

ORIGINALITY REPORT

13%
SIMILARITY INDEX

PRIMARY SOURCES

1	elibrary.tucl.edu.np:8080 Internet	214 words — 1%
2	www.mofe.gov.np Internet	213 words — 1%
3	gggi.org Internet	149 words — 1%
4	www.erpublication.org Internet	140 words — 1%
5	unfccc.int Internet	130 words — 1%
6	www.coursehero.com Internet	104 words — 1%
7	www.osti.gov Internet	99 words — 1%
8	www.un.org Internet	98 words — 1%
9	Tri Ratna Bajracharya, Shree Raj Shakya, Anzoo Sharma. "Climate change and sustainable energy systems", Elsevier BV, 2022	90 words — 1%

Crossref

10	elibrary.tucl.edu.np Internet	90 words — 1%
11	www.mdpi.com Internet	74 words — < 1%
12	wecs.gov.np Internet	71 words — < 1%
13	conference.ioe.edu.np Internet	57 words — < 1%
14	mofe.gov.np Internet	56 words — < 1%
15	nepalindata.com Internet	47 words — < 1%
16	mepr.gov.ua Internet	45 words — < 1%
17	www.ecolex.org Internet	35 words — < 1%
18	www.opml.co.uk Internet	33 words — < 1%
19	Bajracharya, Iswor, and Nawraj Bhattarai. "Road Transportation Energy Demand and Environmental Emission: A Case of Kathmandu Valley", Hydro Nepal Journal of Water Energy and Environment, 2016. Crossref	32 words — < 1%
20	repository.unescap.org Internet	32 words — < 1%

21	hdl.handle.net	Internet	30 words — < 1%
22	www.sei.org	Internet	30 words — < 1%
23	1p5ndc-pathways.climateanalytics.org	Internet	29 words — < 1%
24	repository.nauss.edu.sa	Internet	27 words — < 1%
25	mdpi-res.com	Internet	26 words — < 1%
26	www.adb.org	Internet	26 words — < 1%
27	vbook.pub	Internet	25 words — < 1%
28	docsdrive.com	Internet	23 words — < 1%
29	www.moen.gov.np	Internet	21 words — < 1%
30	www.acf.hhs.gov	Internet	19 words — < 1%
31	www.eappool.org	Internet	18 words — < 1%
32	ee.cnind.org	Internet	17 words — < 1%

33 Ghimire, Krishna Prasad, and Shreejan Ram Shrestha. "Estimating Vehicular Emission in Kathmandu Valley, Nepal", International Journal of Environment, 2014.
Crossref
16 words — < 1%

34 etd.aau.edu.et
Internet
16 words — < 1%

35 journals.riverpublishers.com
Internet
16 words — < 1%

36 www.gov.nl.ca
Internet
16 words — < 1%

37 unesdoc.unesco.org
Internet
15 words — < 1%

38 inis.iaea.org
Internet
14 words — < 1%

39 www.gggi.org
Internet
14 words — < 1%

40 dokumen.pub
Internet
13 words — < 1%

41 Ada Shereen Hosein, Jonathan Whale, Yeliz Simsek, Tania Urmee. "Exploring energy policy scenarios to transition to a low carbon economy by 2050: A case study on the Northern Territory of Australia", Energy Policy, 2023
Crossref
12 words — < 1%

42 eprints.utar.edu.my
Internet
12 words — < 1%

43	julkaisut.valtioneuvosto.fi Internet	12 words — < 1%
44	Saritha Sudharmma Vishwanathan, Amit Garg, Vineet Tiwari, Manmohan Kapshe, Tirthankar Nag. "SDG implications of water-energy system transitions in India, for NDC, 2 °C, and well below 2 °C scenarios", Environmental Research Letters, 2021 Crossref	11 words — < 1%
45	m.moam.info Internet	11 words — < 1%
46	www.econstor.eu Internet	11 words — < 1%
47	"Ageing Asia and the Pacific in Changing Times", Springer Science and Business Media LLC, 2022 Crossref	10 words — < 1%
48	Aggarwal, Preeti, and Suresh Jain. "Energy demand and CO2 emissions from urban on-road transport in Delhi: current and future projections under various policy measures", Journal of Cleaner Production, 2014. Crossref	10 words — < 1%
49	Tiina Koljonen, Antti Lehtilä. "The impact of residential, commercial, and transport energy demand uncertainties in Asia on climate change mitigation", Energy Economics, 2012 Crossref	10 words — < 1%
50	article.sciencepublishinggroup.com Internet	10 words — < 1%
51	d-nb.info Internet	10 words — < 1%

52	eira.energycharter.org Internet	10 words — < 1%
53	www.science.gov Internet	10 words — < 1%

EXCLUDE QUOTES	ON	EXCLUDE SOURCES	< 10 WORDS
EXCLUDE BIBLIOGRAPHY	ON	EXCLUDE MATCHES	< 10 WORDS