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THESIS NO: M-373-MSREE-2019-2023

ENERGY FORECASTING AND IMPACT ASSESSMENT OF ELECTRIC VEHICLES IN NEPAL

BY

SUBIR KARN

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

OCTOBER, 2023

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Date: 4th October 2023

ABSTRACT

The transportation sector in Nepal is heavily reliant on imported fossil fuels, which is costly and polluting. The increasing adoption of electric vehicles (EVs) is likely to put unnecessary stress on the existing electrical infrastructure. The study focuses on the forecasting the energy and electricity demand in Nepal due to increasing adoption of the electric vehicles. The survey was designed based on the Krejices Morgans sampling method and a total of 555 sample were taken. Based on the outcomes of the survey, the overall energy consumption in transportation sector in 2022 was estimated to be 64.92 PJ out of which diesel accounted for the 39.27 PJ, followed by petrol at 25.28 PJ and electricity consumption at 0.08 PJ.

The base year energy demand was forecasted based on the service demand projection methodology. Based on the historical trend of energy use in transportation sector along with the plans and policies of the Government of Nepal three scenarios, namely business as usual (BAU), sustainable development (SD) and net zero emission (NZE), were prepared. The BAU scenario reflects historical trends in vehicle usage in Nepal and under the scenario overall energy demand has been expected to increase to 92.41 PJ by 2030 and 180.46 PJ by 2050. The compound annual growth rate (CAGR) of energy demand in this scenario is projected to be 4.55% while the electricity as a transportation fuel is expected from 0.07PJ in 2022 to 0.64 PJ in 2045. The greenhouse gas emission in this scenario has been forecasted to reach 11.39 $mMTCO_{2eq}$ by 2045. In the SD scenario, the overall energy demand has been projected to reach 68.35 PJ by 2030 and 106.94 PJ by 2045 The electric demand in the SD scenario is projected to increase at a CAGR of 26.68%. The GHG emissions in this scenario are projected to reach 6.55 $mMTCO_{2eq}$ by 2050. In the Net-Zero Emission scenario, the overall energy demand has been expected to increase to 70.27 PJ by 2030 and then decline to 36.94 PJ by 2050. Energy consumption has been anticipated to increase till 2030 and then decrease until 2045 due to the increased adoption of clean energy vehicles. The demand of electricity in the NZE scenario is expected to grow at CAGR of 31.12%. The GHG emissions in this scenario have been projected to reach 4.10 $mMTCO_{2eq}$ by 2030 and achieve net-zero emissions by 2045.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisors, Associate Professor Dr. Ajay Kumar Jha, Department of Mechanical and Aerospace Engineering, Pulchowk Campus, and Assistant Professor Mr. Arbin Maharjan, Department of Electrical Engineering, for their invaluable support and guidance throughout all stages of my research.

I would also like to thank Associate Professor Dr. Hari Bahadur Darlami, Programme Coordinator, Masters in Renewable Energy Engineering, and Dr. Nawaraj Bhattarai, Department of Mechanical and Aerospace Engineering, for their valuable input and time during the study.

In addition, I would like to express my appreciation to the Centre for Pollution Studies and the Research Coordination and Development Council (RCDC), Tribhuvan University, project code number "TU-NPAR-079/80-ERG-05", for their technical and financial support in carrying out my thesis.

Finally, I would like to thank my parents and family members for their continuous encouragement. I would also like to extend my sincere gratitude to everyone who has directly or indirectly helped me during this thesis.

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LIST OF ABBREVIATION

ABC	Atmospheric Brown Clouds
AEPC	Alternative Energy Promotion Center
ATF	Aviation Turbine Fuel
BAU	Business As Usual
CBS	Central Bureau of Statistic
CEN	Clean Energy Nepal
CGE	Computable General Equilibrium
CNG	Compressed Natural Gas
DC	Direct Current
EST	Environmentally Sustainable Transport
EV	Electric Vehicles
EVSE	Electric Vehicle Supply Equipment
FY	Fiscal Year
GDP	Gross Domestic Product
GHG	Green House Gases
GoN	Government of Nepal
GVA	Gross Value Added
HDV	Heavy Duty Vehicle
IAEA	International Atomic Energy Agency
ICE	Internal Combustion Engine
IEA	International Energy Agency
LEAP	Low Emission Analysis Platform
LPG	Liquefied Petroleum Gas
LTS	Long Term Strategy
LDVs	Light Duty Vehicles
MAED	Model For Analysis of Energy Demand
MDV	Medium Duty Vehicle
MoFE	Ministry of Forests and Environment
MoHP	Ministry of Health and Population
NAP	National Planning Commission
NDC	Nationally Determined Contribution

NEA	Nepal Electricity Authority
NEMS	National Energy Modeling System
NI	Northern Ireland
SDG	Sustainable Development Goals
SEI	Stockholm Environment Institute
SNDC	Second Nationally Determined Contribution
SWOT	Strength Weakness Opportunities Threats
TIMES	The Integrated MARKAL-EFOM System
TOR	Terms of Reference
UNDESA	United Nation Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program
WASP	Wien Automatic System Planning Package
WECS	Water and Energy Commission Secretariat
WEM	World Energy Model
ZEV	Zero Emission Vehicle

CHAPTER ONE: INTRODUCTION

1.1 Background

The transportation sector in Nepal is highly reliant on fossil fuels, particularly petrol and diesel. Over the past few decades, there has been a significant increase in the number of internal combustion (IC) engine vehicles, and since 2016, this number has doubled. In order to meet the growing demand for transportation, the Government of Nepal has been importing a substantial amount of fossil fuels and providing them at subsidized rates, which has led to substantial financial losses. Currently, the Nepal Oil Corporation (NOC) experiences a monthly net loss of NPR 3.09 billion due to these subsidies, with NPR 665 per cylinder on LPG, NPR 16.28 per liter on petrol, and NPR 11.78 per liter on diesel being the main contributing factors (NOC, 2022).

With the increase in generation of electricity, the country has finally reached a stage where it has been able to export electricity to neighboring countries like India especially in the wet season. In the year 2021/22, the government has exported 493.61 GWh of energy. The country has further set the plans for increasing the generation of electricity in the upcoming years. Further the country has planned to increase the specific electricity consumption from 351 kWh /capita in 2022/23 to 1,500 kWh/capita by 2030 (SDG, 2016). The use of electric vehicles in can further create sufficient electricity demand in future and assist the county in utilizing the electricity generation within the country while also increasing the electricity demand.

The adoption of electric vehicles can therefore offer a sustainable solution to reduce reliance on imported fossil fuels along with mitigating green house gases (GHG) emission, and promote energy security in the country. In recognition of these benefits, the Government of Nepal has taken concrete steps to bolster the adoption of electric vehicles through various policy frameworks, such as the Second Nationally Determined Contribution, Long Term Strategy for Net Zero Emission, and the 15th Periodic Plan. To support the transition to electric mobility, the government has implemented a range of incentives and measures. Tax exemptions, subsidies, and preferential treatment in licensing and registration have been introduced to make electric vehicles more financially viable and accessible for consumers.

The growing adoption of electric vehicles in Nepal presents a positive step towards sustainability, but it also brings new challenges for the energy sector. The uncoordinated or haphazard adoption of electric vehicles without adequate planning can lead to significant stress on the electricity generation and distribution infrastructure, potentially causing power shortages or cut. This study aims to develop scenario-based projections to assess the impact of electric vehicles on energy generation. By using various scenarios, the study will estimate the potential increase in electricity demand due to the widespread use of electric two-wheelers, buses, and cars

1.2 Problem Statement

The transportation sector in Nepal heavily relies on imported fossil fuels, making it susceptible to fluctuating international market prices and imposing a significant economic burden. In FY 2021/22, Nepal spent NPR 292.77 billion on imported petroleum products, witnessing an 88.7% increase compared to the previous year (NRB, 2022). Additionally, the use of traditional internal combustion engine (ICE) vehicles contributes to severe air pollution, leading to adverse health effects. To combat these issues and promote sustainability, the adoption of electric vehicles is considered a viable solution to reduce dependency on imported fossil fuels, mitigate air pollution, and enhance energy security.

However, the widespread adoption of electric vehicles is not without challenges. As the adoption rate of electric vehicles increases, the demand for electricity will surge, putting stress on the existing electricity generation infrastructure. Furthermore, the lack of sufficient charging stations is a major barrier to the promotion of electric vehicles in Nepal. This thesis aims to address these challenges by conducting a comprehensive analysis of the scenario-based electricity demand projection, accounting for the anticipated growth in electric vehicle adoption. Furthermore, this study will estimate the number of charging stations required to support the envisioned electric vehicle fleet in Nepal.

1.3 Objective

The main objective of this research is to evaluate the influence of electric vehicles on electricity generation and emissions reduction in Nepal. The study has outlined specific objectives, which are as follows:

- To analyze the current energy consumption by fuel type and vehicle type in the transport sector of Nepal
- To forecast the energy demand for various vehicle types until the year 2045, with a 5-year interval
- To evaluate the electricity generation needed to support the charging of electric vehicles in Nepal
- To estimate the required number of public charging points for passenger vehicles in Nepal

1.4 Limitations of the Study

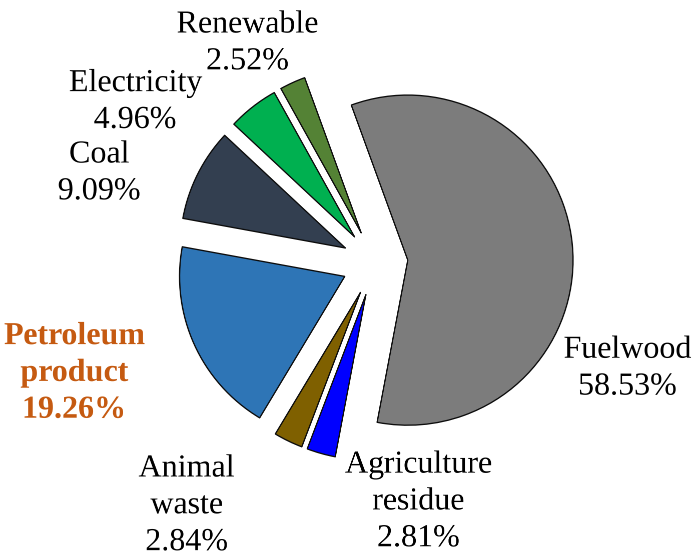
Although a comprehensive study was undertaken to determine the study's outputs, there were certain limitations that arose during the research. These limitations include:

- Study considers carbon dioxide (CO_2), methane (CH_4) & nitrous oxide (N_2O) as GHG emissions
- Study does not consider vehicles used in construction as transportation sector
- Study does not take into account the potential of hydrogen vehicles and other emerging electric vehicle technologies.
- Rail transport and aviation has not been considered during the study

CHAPTER TWO: LITERATURE REVIEW

2.1 Energy Supply and Consumption Situation

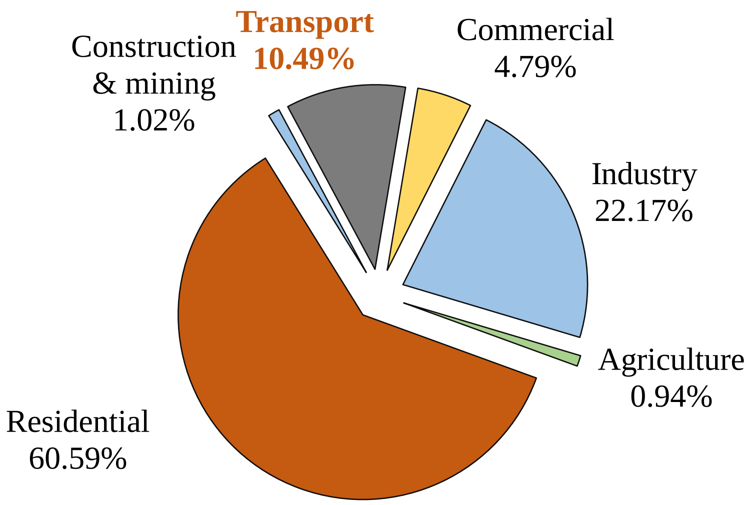
The total energy consumption of Nepal in the year 2022 was 640 PJ and is increasing at a compound annual growth rate (CAGR) of 3.44% since 2009 (WECS, 2023). As Nepal has no petroleum and reserved coal, so the primary energy source is Biomass such as fuelwood. Firewood comprises of 58.53% of the total energy, which is the major source of energy consumption, followed by petroleum products (19.26%). The remaining sources of energy consumption are coal (9.09%), electricity (4.96%), animal waste (2.84%), agricultural residue (2.81%), and renewable (2.52%). The overall energy consumption segregated by the fuel use in Nepal is shown in Figure 2-1.



(WECS, 2023)

Figure 2-1: Share of fuels in energy consumption

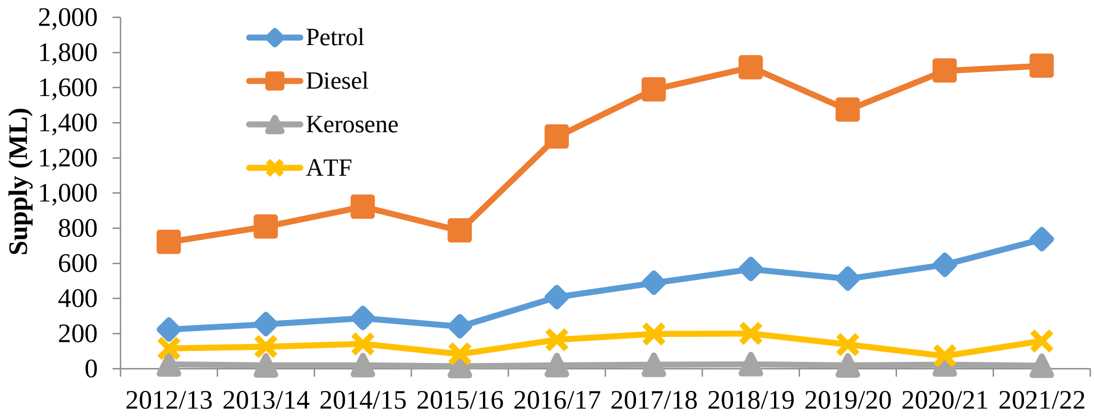
With the modernization of the country and the mechanization in the commercial and industrial sectors, the trend of energy consumption, especially in the commercial, industrial, and transport sectors is growing rapidly while the share of energy consumption in the residential sector is in a downward trend. In the year 2022, the share of energy consumption for residential, industrial, commercial, transportation, and other sectors has been estimated to be 60.59%, 22.17%, 4.79%, 10.49% and 1.02%, respectively.



(WECS, 2023)

Figure 2-2: Sectoral energy consumption

The supply pattern of petroleum products in Nepal is depicted in Figure 2-3. Over the years, there has been a steady growth in the supply of diesel, petrol, and aviation turbine fuel (ATF) with annual increases of 9.10%, 12.68%, and 3.09%, respectively. Diesel remains the most extensively consumed petroleum product each fiscal year, owing to its wide usage in infrastructure development, heavy equipment, freight vehicles, agriculture, and industries. On the other hand, kerosene is currently undergoing a phase-out process, leading to an annual decrease of 3.22% in its consumption."

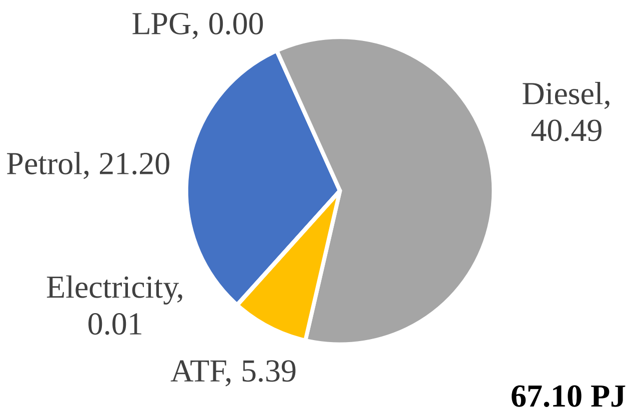


(NOC, 2023)

Figure 2-3: Supply of petroleum product

2.2 Energy Consumption in Transportation Sector

The energy consumption in the transport sector is mainly dominated by petrol and diesel followed by aviation turbine fuel, electricity and LPG. In 2022, the overall energy consumption in transportation sector in Nepal was 67.10 petajoule (PJ). Out of which 60.34% is due to the consumption of diesel followed by petrol consumption at 31.60% and ATF consumption at 8.04%. The overall energy consumption in transportation sector in Nepal is shown in Figure 2-4.



(WECS, 2023)

Figure 2-4: Energy consumption by fuel in transportation sector

Nepal has set its goal to achieve net zero emissions by 2045. However, the energy sector GHG emission in 2019 was 17.18 CO_{2eq} as shown in Table 2-1. In Nepal, the residential sector contributes to the majority of the emissions followed by the transportation sector. The emission from transport sector is reported to be 5.15 CO_{2eq}. Increasing electrification in the transport sector would help to curb out a major portion of GHG emissions in Nepal.

Table 2-1: Emission in Nepal from energy sector (million metric tonnes), 2019

Sectors	Methane (CH_4)	Nitrous oxide (N_2O)	Carbon dioxide (CO_2)	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

Sectors	Methane (CH_4)	Nitrous oxide (N_2O)	Carbon dioxide (CO_2)	CO_2 equivalent
Agricultural	0.00	0.00	0.78	0.78
Total	**0.85**	**3.74**	**12.59**	**17.18**

(LTS, 2021)

2.3 Vehicles in Nepal

The vehicle growth in Nepal has been significant in recent years, with an increase in both the number of vehicles on the road and the types of vehicles being used. According to the Economic Survey 2022/23, the number of vehicles registered in Nepal has reached 5,260,161and has increased at an annual growth rate of 17.38% over the last five years. Based on the type of vehicles, motorcycle and scooter are the mostly used vehicles at 80.71% followed by car/jeep/van at 6.31%.

Table 2-2:Vehicles registered in Nepal till 2022/23

S.N.	Vehicle	Number of vehicles registered
1.	Motor cycle	4,266,566
2.	Tempo	92,476
3.	Car/jeep/Van	322,119
4.	Micro bus	11,715
5.	Mini bus	18,740
6.	Bus	64,647
7.	Truck/Mini truck	144,501
8.	Pick up	90,512
9.	Tractor	184,282
10.	E rickshaw	55,585
11.	Others	9,019
	Total	5,260,161

(MOF, 2022)

In 2014, Malla conducted a study to assess the operating factors of various types of road transport in Nepal. The study revealed for passenger vehicles in Kathmandu valley, the micro bus exhibited the highest operating factor at 0.55. Conversely, in the rest of the country, the tempo showed the highest operating factor at 0.58. Regarding motorized freight, the study found that pick-up trucks had the highest operating factors, reaching 0.68 in Kathmandu valley and 0.70 in the rest of the country.

Table 2-3:Opearating factors of road transport

Vehicle	Kathmandu	Rest of the country	Weighted average
Motor cycle	0.50	0.60	0.55
Tempo	0.29	0.58	0.48
Car/jeep/Van	0.40	0.40	0.40
Micro bus	0.55	0.55	0.55
Mini bus	0.39	0.45	0.40
Bus	0.45	0.42	0.43
Truck	0.39	0.39	0.39
Mini truck	0.37	0.45	
Pick up	0.68	0.70	0.69
Tractor	0.11	0.50	0.49

(Malla, 2014)

The emission arising from the combustion of fuel in the electric vehicle can be described as the function of the fuel consumed in the vehicle. The *"Emission Inventory Manual"* published by the United Nation Environment Programme in 2012 has listed out the emission factors for different fuels used in different vehicles based on International Panel on Climate Change (IPCC) tiered approach as illustrated in table

Table 2-4: Emission factors for road transport (g/kg)

Vehicle	Fuel	Carbon dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_20)
Car/Jeep/Van	Petrol	3,060	1.7	0.14
Car/jeep/van	Diesel	3,211	0.08	0.17
Motorcycle	Petrol	1,710	5.2	0.14
Tempo	LPG	2,985	2.9	0.009
Tempo	Petrol	3,060	1.24	0.14
Microbus	Diesel	3,090	0.08	0.17
Microbus	LPG	2,985	2.9	0.009
Bus	Diesel	3,090	0.25	1.7
Truck	Diesel	3,090	0.25	1.7
Tractor	Diesel	3,090	0.25	1.7
Pickup	Diesel	3,090	0.25	1.7

2.3.1 Electric Vehicles in Nepal

The use of electric vehicles in Nepal is still in early stages but the interest towards electric vehicle is increasing. Currently the electric vehicles in Nepal is limited to passenger vehicles mostly motorcycles and tempos and E rickshaw. According to the Vehicle Testing Station, the number if electric vehicle in Nepal up to 2021/22 is 19,551 (Vehicle Testing Station, 2022). The share of different type of electric vehicle is shown in Table 2-5.

Table 2-5: Electric vehicles in Nepal

Vehicle Type	Numbers
Motorcycle	9,092
Car	2,924
Bus	22
Microbus/Van	240
Tempos and E-rickshaw	7,273

(Vehicle Testing Station, 2022 unpublished)

2.4 Low Carbon Transport Related Studies in Nepal

The transportation sector is a crucial component of energy consumption and greenhouse gas (GHG) emissions in Nepal. Numerous studies have been conducted to examine energy consumption and emissions from the transportation sector. Gautam, Sharkya & Nakarmi (2020) employed the Model for Analysis of Energy Demand (MAED) model to generate various scenarios at varying growth rates to analyze the increase in energy demand across diverse economic sectors. The research indicates that, under the low-growth scenario (4.5% growth rate), energy demand in the transportation sector will increase by 5.5 times from 2017 to 2040. Similarly, under the medium-growth scenario (7-8% growth rate), energy demand will increase by 6.9 times, and under the high-growth scenario (9.2% growth rate), energy demand will increase by 8.6 times.

According to a 2019 report by Clean Energy Nepal (CEN), 68% of LDVs (Light Duty Vehicles) in Nepal are powered by petrol. The study also indicates that the average liter gasoline equivalent (Lge) per 100 km has decreased by 20% between 2005 and 2016. The trend in average Lge per 100 km varies by vehicle type, with cars, jeeps, vans, and pickups showing a declining trend, while motorcycles are showing an increasing trend, as indicated in Table 2-6 . The report further suggests that the average CO_2 emissions from vehicles registered between 2005 and 2016 are decreasing annually by 1.3%.

Table 2-6: Weighted average Lge per 100 km based on vehicle type

Type	2005	2008	2010	2012	2014	2016
Car	6.19	6.34	5.85	5.57	5.36	4.92
Jeep	9.00	9.11	8.24	8.18	7.19	7.19
Van	6.29	6.29	6.03	6.27	6.10	6.09
Pickup	10.52	9.31	9.16	8.02	6.76	6.85
Microbus	9.19	10.71	10.79	10.99	10.72	10.78

(Source: CEN, 2019)

Malla (2014) conducted a study that estimated the energy consumption of Nepal's transportation sector to be 816 ktoe, which was more than two-thirds of the petroleum product use in the country. The study further revealed that private passenger vehicles consumed approximately 59% of the energy used in road transportation in the Kathmandu Valley, whereas in the rest of the country, private passenger vehicles consumed around 55% of the total energy used in road transport. The study also demonstrated that freight transport was responsible for 55% of CO_2 emissions, followed by private passenger transport at 24%, and public passenger transport at 21% in the country.

Shakya (2014) investigated the consequences of the introduction of electricity in the transportation sector using a multi-sector, single-region, recursive dynamic computable general equilibrium (CGE) model of Nepal. The research revealed that increasing the electrification of road transportation by 10% until 2020, and then becoming constant thereafter would result in a cumulative real GDP increase of 2.8% during 2005 to 2050. Furthermore, a 10% rise until 2020 and 20% by 2050 would increase the GDP by 2.6%, and a 10% increase by 2020 and 30% by 2050 would increase the GDP by 3.1% compared to the base case.

Shrestha and Shakya (2012) investigated the consequences of three distinct scenarios for CO_2 emission reduction targets on the energy supply mix and local pollutant emissions. The study predicted that if there are no restrictions on CO_2 emissions (scenario 1a), the cumulative share of CO_2 emissions from the transportation sector between 2005 and 2100 will be 27%. In contrast, the cumulative share of emissions will decrease to 6% and 9% in scenario ERT 20 (which has a cumulative CO_2 emission reduction target of 20%) and scenario ERT 40 (which has a cumulative CO_2 emission reduction target of 40%), respectively. Additionally, scenario ERT 40 + EMT 30 (which involves a 30% increase in the share of electric mass transport by 2050 with a cumulative CO_2 emission reduction target of 40%) predicts that the cumulative share of CO_2 emission by 2100 will be 15%. In terms of cumulative final energy consumption from the transportation sector, scenario 1a projects 18,547 PJ from 2005 to 2100, while scenario ERT 20, ERT 40, and ERT 40+EMT 30 project 559 PJ, 1,563 PJ, and 3,092 PJ, respectively.

In Nepal, Kathmandu Valley is a significant contributor to the country's overall greenhouse gas (GHG) emissions due to hosting over one-fourth of the country's vehicles. Ghimire and Shrestha (2014) conducted a study to estimate vehicular emissions in Kathmandu Valley. The study found that in the base year, the total vehicular emissions in the valley were 7.23 million tonnes/year, with CO_2 emissions accounting for 91.01%, followed by CO at 5.03%, HC at 0.96%, NO_X at 0.60%, PM_{10} at 0.18%, and SO_2 at 0.10%. Heavy-duty vehicles were found to be the biggest emitters, contributing 50% of the total emissions, followed by light-duty vehicles at 27%, 2-wheelers at 22%, and 3-wheelers at 1%.

Bajracharya and Bhattarai (2016) conducted a study to determine the energy and emission form transportation sector in Kathmandu Valley based on scenario-based approach. The study highlighted that the cumulative energy demand by 2030 in the transportation sector can be reduced by 9%, CO_2 by 9% and PM_{10} by 10% if the vehicle fuel efficiency is increased by 30%. Similarly, if the sales of gasoline motorbike are replaced with electric motorbike by 75%, the cumulative energy demand can be reduced by 12%, CO_2 emission by 7%, HC by 29% and PM_{10} by 20%. Likewise with the penetration of plug-in hybrid electric car (75% of the total car) can decrease the energy consumption by 1%, CO_2 emission by 2%, and PM_{10} by 10%. Similarly, with the increase in share of electric public bus transport to 75% the reduction in energy demand, CO_2 emission, and PM_{10} can be 18%, 36% and 30%.

Similarly, Shrestha et al. (2013) conducted a study to analyze the pollutants emitted by various modes of transportation i.e., including buses, vans, three-wheelers, taxis, and motorcycles in Kathmandu Valley, and compared them to the Euro III vehicle standard. The study found that major pollutants from transportation sector in Kathmandu Valley, i.e., CO, VOC, NO_x, PM, BC, and CO_2, were 31, 7.7, 16, 4.7, 2.1, and 1,554 Gg, respectively. The study concluded that if all vehicles complied with the Euro III standard, the emissions would decrease by 44% for toxic air pollutants (excluding CO_2) and 31% for climate-forcers in terms of the 20-year horizon CO_2-equivalent compared to the base case.

Shrestha and Rajbhandari (2010) conducted a study to investigate the potential impact of carbon reduction targets in the Kathmandu Valley on energy consumption and the environment. The study suggests that the projection of service demand for passenger vehicles depends on changes in the GDP and population of the region, while for freight transport, it mainly depends on the GDP. The study determined the elasticity of population and GDP in passenger vehicles to be 1.44 and 0.41, respectively, and the GCP elasticity for freight vehicles to be 0.6. Furthermore, the study analyzed the effect of emission reduction targets on the energy mix in the Kathmandu Valley. It projected that the transportation sector's energy consumption would increase to 11.41 PJ by 2020 and 20 PJ by 2050. The study highlights that the proportion of electricity in the energy mix would rise from approximately 12% in the base case to 24% in the ER 30 scenario (a 30% emission reduction target). The study concludes that the cumulative CO2 emissions from the transportation sector would decrease from 49,728 kt in the base case to 39,162.6 kt in the ER 30 scenario.

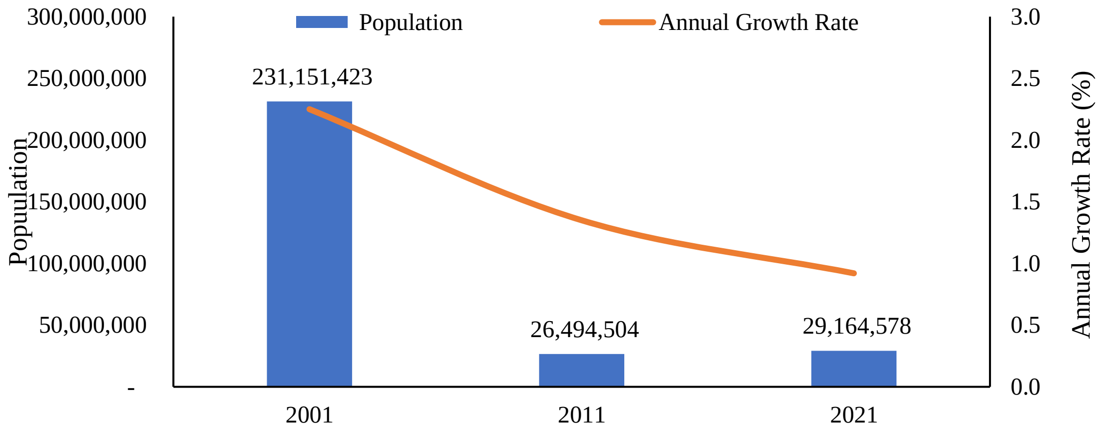
2.5 Macroeconomic status

Macroeconomic conditions play a crucial role in energy forecasting. Macroeconomic indicators such as GDP growth, inflation, and population growth, among others, can significantly influence energy demand patterns over time. For instance, higher GDP growth rates are often associated with higher energy demand as businesses and households increase their consumption of energy-intensive goods and services and vice versa.

2.5.1 Population

The growth of the population plays a crucial role in predicting the future energy requirements. It has the potential to greatly influence energy demand and resource availability within a specific area. With a larger population, the demand for energy typically rises, potentially leading to the need for new energy infrastructure and production facilities. Furthermore, the increase in population can also lead to higher demands for transportation, encompassing both passenger and freight vehicles.

As per the CBS (Central Bureau of Statistics) 2021 report, Nepal is experiencing a consistent rise in its population, with an annual growth rate of 0.92%. As of 2021, the total population has surpassed 29 million. The urban population is expanding at an even faster pace of 1.44%, and it currently makes up 66% of the total population. The overall population and the growth rate in Nepal is shown in Figure 2-5 .



(CBS, 2022)

Figure 2-5: Population and growth rate of Nepal

Based on the *"World Population Prospects"* of the United Nation Demographic and Social Affairs (UNDESA) the population growth rate in Nepal will further decline and reach 0.56% by 2045. The population growth rate of the Nepal in over the five years interval is shown in Table 2-7.

Table 2-7: Populaion growth rate in Nepal

Period	Population growth rate (%)
2022-2025	1.19%
2025-2030	0.93%

Period	Population growth rate (%)
2030-2035	0.77%
2035-2040	0.69%
2040-2045	0.56%

(Based on the World Population Prospects)

2.5.2 Gross Domestic Product

The Gross Domestic Product (GDP) of Nepal at constant 2011 price in the year 2022/23 was NPR 2,576 billion with an increase of 2.15% in the current fiscal year, while in the previous year the growth in the GDP was 5.26%. The share of the transportation and storage in the overall GDP of the Nepal in FY 2022/23 was around 5.40% with a growth rate of 1.14% (CBS, 2022). The historical pattern for the change in GDP in Nepal is shown in Table 2-8.

Table 2-8: GDP of Nepal (at constant 2010/11 price)

Year	Overall		Transportation and storage	
	In million NPR	Growth (%)	In million NPR	Growth (%)
2010/11	1,436,072		77,194	
2011/12	1,507,172	4.95%	82,508	6.88%
2012/13	1,553,502	3.07%	89,324	8.26%
2013/14	1,642,711	5.74%	95,033	6.39%
2014/15	1,700,405	3.51%	100,638	5.90%
2015/16	1,700,448	0.00%	100,812	0.17%
2016/17	1,846,506	8.59%	105,258	4.41%
2017/18	1,982,653	7.37%	117,552	11.68%
2018/19	2,109,263	6.39%	127,863	8.77%
2019/20	2,058,149	-2.42%	112,783	-11.79%
2020/21	2,150,497	4.49%	117,785	4.44%
2021/22	2,263,570	5.26%	123,213	4.61%
2022/23	2,312,383	2.16%	124,622	1.14%

(CBS, 2022)

2.6 Energy System Models: A Review

Energy system models are mathematical models that are developed to represent various energy-related problems. These models can guide decision-making on power capacity expansion by illustrating different strategies to meet future demands and environmental targets. Typically, energy modelling tools can be categorized based on three groups based on the approach used for the energy model.

2.6.1 Top-Down Energy Model

Top-down energy modeling is a methodology used to estimate the energy consumption and greenhouse gas emissions of a region, country, or the world as a whole. This approach starts by looking at aggregate data, such as gross domestic product and population, and then estimating energy use and emissions based on this data. The models used in top-down energy modeling can be simple or complex and may incorporate a range of assumptions and data sources. Despite some limitations, top-down energy modeling is useful for providing a high-level understanding of energy consumption and emissions trends, as well as identifying areas for policy intervention.

2.6.2 Bottom-Up Energy Model

Bottom-up energy modeling is an approach that involves analyzing the energy consumption of individual buildings, processes, or equipment, and then aggregating the results to estimate energy use and greenhouse gas emissions at the regional or national level. This method starts with detailed data on energy use and emissions at the individual level and uses this information to build up a comprehensive picture of energy consumption and emissions across a region or country. Bottom-up energy modeling can provide a more detailed understanding of energy use and emissions trends and is useful for identifying specific areas where energy efficiency improvements can be made. However, it can be resource-intensive and may not capture all of the complexities of the energy system.

2.6.3 Hybrid Energy Model

A hybrid energy model is a methodology that combines elements of both top-down and bottom-up energy modeling. This approach uses both aggregate data and detailed information on individual buildings, processes, or equipment to estimate energy consumption and greenhouse gas emissions. Hybrid energy modeling aims to overcome some of the limitations of top-down and bottom-up modeling by providing a more comprehensive and accurate picture of the energy system. By combining the strengths of both approaches, hybrid energy modeling can provide insights into energy consumption and emissions trends at different levels of detail and can be useful for identifying opportunities for energy efficiency improvements and policy intervention. Examples of hybrid models include The Integrated MARKAL-EFOM System (TIMES) and the Long-range Energy Alternatives Planning System (LEAP).

The selection of energy modelling tools relies on various factors, such as the scope and magnitude of the analysis, data accessibility, as well as the advantages and disadvantages of different types of energy modelling tools. Some of the generally used energy modelling tools are described in the Table 2-9.

Table 2-9: Different types of energy modelling tool

S.N.	Energy modelling tools	Remarks	References
1.	Low Emission Analysis Platform (LEAP)	LEAP is an integrated, scenario-based modeling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks. In addition to tracking GHGs, LEAP can also be used to analyze emissions of local and regional air pollutants, and short-lived climate pollutants (SLCPs) making it well-suited to studies of the climate co-benefits of local air pollution reduction. LEAP supports a wide range of different modeling methodologies: on the demand side these range from bottom-up, end-use accounting techniques to top-down macroeconomic modeling. LEAP also includes a range of optional specialized methodologies including stock-turnover modeling for areas such as transport planning. On the supply side, LEAP provides a range of accounting, simulation and optimization methodologies that are powerful enough for modeling electric sector generation and capacity expansion planning, and which are also sufficiently flexible and transparent to allow LEAP to easily incorporate data and results from other more specialized models.	(LEAP, 2023)
2.	Model for Analysis of Energy Demand (MAED)	MAED 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	(IAEA, 2023)

S.N.	Energy modelling tools	Remarks	References
		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, electricity for specific uses (electrolysis, lighting etc.) are calculated directly in terms of final energy	
3.	The Integrated MARKAL-EFOM System (TIMES)	TIMES is an energy modelling tool that integrates the MARKAL (MARKet ALlocation) and EFOM (Energy Flow Optimization Model) models to provide a more comprehensive analysis of energy systems. It uses mathematical optimization techniques to identify the least-cost pathways for meeting energy demand, while accounting for various constraints such as technology availability, environmental regulations, and market conditions. TIMES allows users to model multiple energy sectors and technologies, including electricity generation, transportation, and industrial processes, as well as the interactions between different parts of the energy system. The tool can be used to analyze the impacts of different policy scenarios and investment decisions, and has been used by government agencies, energy companies, and research organizations around the world to inform energy policy and planning. The integration of MARKAL and EFOM in TIMES provides a more complete picture of energy systems, making it a powerful tool for energy system optimization and policy analysis.	(ETSAP, 2023)
4,	Model for Energy Supply Strategy	MESSAGE is a complex system engineering optimization model that is widely used to plan medium to long-term energy systems and analyze the impact of climate change policies. It can	(IAEA, 2023)

S.N.	Energy modelling tools	Remarks	References
	Alternatives and their General Environmental Impacts (MESSAGE)	simulate various thermal generation, renewable, storage and conversion, and transport technologies as well as carbon sequestration. Although the inputs for the model are highly detailed on the supply side, they are more aggregated on the demand side. The model provides global and regional, multi-sector mitigation strategies, rather than climate targets. It is capable of determining cost-effective portfolios of GHG emission limitation and reduction measures, and has been extended to cover a full range of greenhouse gases and other radiative substances. MESSAGE is a central component of the IIASA Integrated Assessment Framework, which includes a range of spatial and regional modelling tools that together represent the global economy and its main sectors, including energy, agriculture, and forestry.	
5.	Wien Automatic System Planning Package (WASP)	WASP is a comprehensive software tool used for power system planning and analysis. It features a user-friendly graphical user interface that makes it easy for users to create, modify and visualize power system models. The tool includes integrated modules for power generation, transmission, and distribution, allowing users to develop complete power system models. Additionally, WASP has optimization capabilities that allow users to perform cost-benefit analyses and evaluate different scenarios for power system expansion and improvement.	(IAEA, 2023)

S.N.	Energy modelling tools	Remarks	References
6.	National Energy modelling System (NEMS)	NEMS is a sophisticated computer model developed by the US Energy Information Administration (EIA) to analyze US energy markets and policy. The model is comprehensive, covering all sectors of the US economy and taking into account economic, social, and environmental factors. NEMS simulates energy production, consumption, and trade in all regions of the United States, including renewable energy sources, fossil fuels, and nuclear power. The model is scenario-based, allowing users to evaluate the impact of different policies and market conditions on energy demand, supply, and emissions.	(EIA, 2019)
7.	World Energy Model (WEM)	WEM is a complex computer-based model developed by the International Energy Agency (IEA) to analyze global energy markets and policy. The model simulates energy production, consumption, and trade in all regions of the world, taking into account economic, social, and environmental factors. It includes detailed data on energy supply and demand, technology costs and availability, and policy frameworks. The WEM is scenario-based, allowing users to evaluate different scenarios for energy demand, supply, and emissions, and to explore the impact of policy measures and market changes. The model is used by policymakers, industry stakeholders, and researchers to inform energy policy decisions and to anticipate future trends in global energy markets.	(IEA, 2023)

2.7 National Policies on Decarbonization of transportation sector

2.7.1 Sustainable Development Goals (SDG-7)

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.

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.

2.7.2 Second Nationally Determined Contribution (NDC)

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. 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.

2.7.3 Nepal's Long-term Strategy for net-zero emissions

Nepal's Long-term Strategy for Net-zero Emissions has been prepared with the objective of development of Net Zero emission by 2050 in different economic sectors. It compares emission reduction in 2030 and 2050 with existing measures and added measures. According to LTS, 1.9 million Metric tons CO_{2eq} emission reduction can be achieved in 2030 and 8.2 million Metric tons CO_{2eq} 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.

2.7.4 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) on 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 programmes 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.

2.7.5 National Action Plan for Electric Mobility

To accelerate the implementation of Nationally determined contribution Global Green Growth Institute 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. 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 plans for overcoming these barriers namely (a) Unit for electric mobility, (b) National program for electric mobility and (c) National financing vehicle for electric mobility.

2.7.6 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. 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.

2.7.7 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.

CHAPTER THREE: METHODOLOGY

3.1 Overall Study Framework

This chapter describes the methodology that has been adopted for the work from initial phase of the research till the completion. The methodology followed for the accomplishment of study is shown in Figure 3-1.

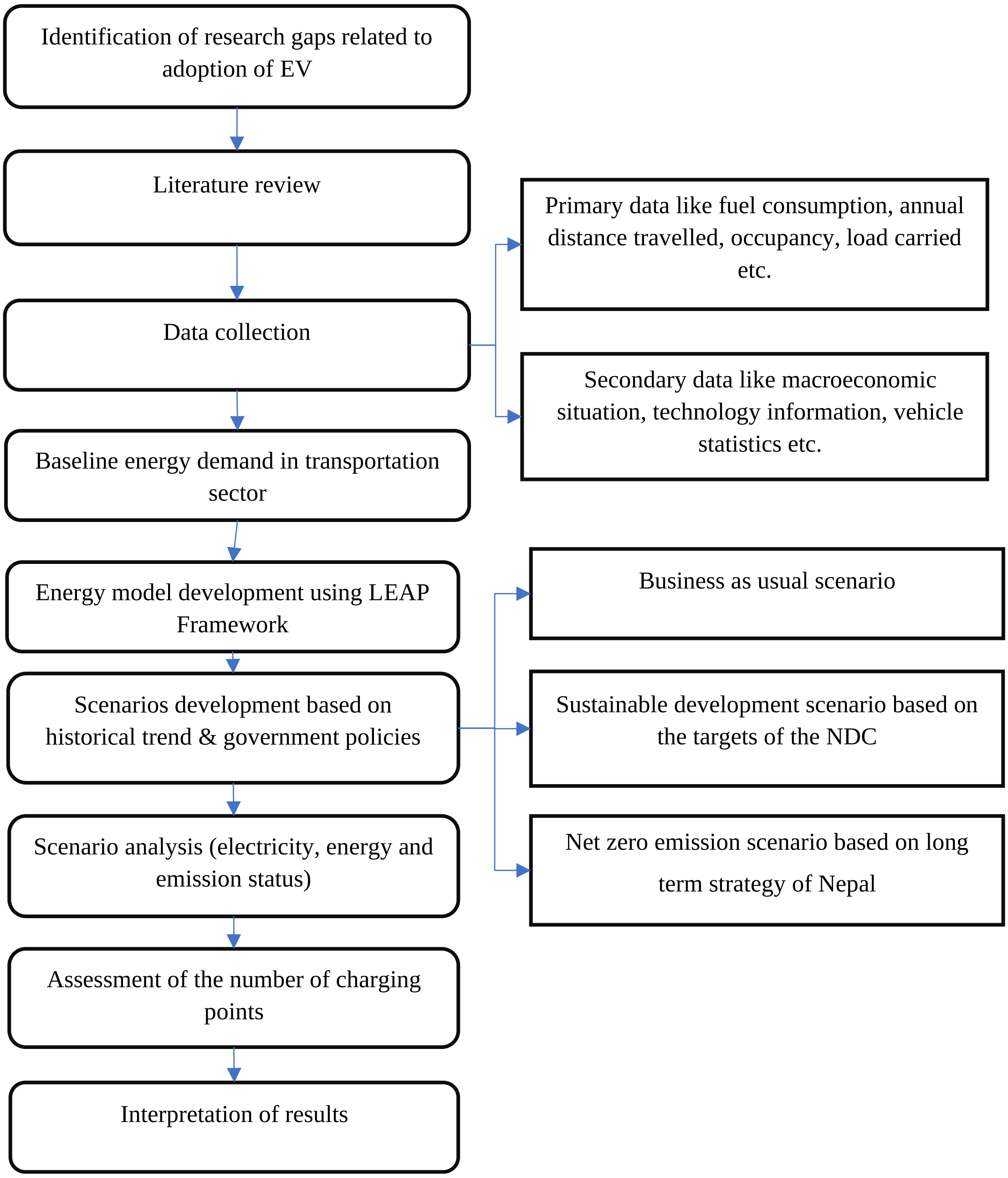


Figure 3-1: Methodological flowchart

3.2 Literature Review

The literature review was conducted to study the status of energy used in the transportation sector along with the statistics and characteristics of different road transportation. Further a thorough review of energy modeling tools and techniques, macroeconomics and GHG emissions was also conducted. In addition, different historical data published by the Central Bureau of Statistics, National Planning Commission, Ministry of Finance, Water and Energy Commission Secretariat etc were thoroughly examined. Similarly, the target set by the government in relation to economic growth and promotion of electric vehicles like second Nationally Determined Contribution (NDC), Long Term Strategy for Net Zero Emission, Nepal Action Plan for Electric mobility, National Energy Efficiency Strategy was thoroughly reviewed. Further different peer reviewed journals and papers related to energy use in transportation sector and integration of electric vehicle in transportation sector was also reviewed during the study.

3.3 Questionnaire Preparation and Pilot Testing

The questionnaire based survey was employed for collection of primary data . A questionnaire incorporating various socioeconomic information, fuel consumption statistic, operating pattern for vehicles was prepared. Before implementation, the questionnaire was pretested in the Lalitpur district and was subsequently modified based on feedback. The questionnaire was also programmed using google forms and the data collection was done through combination of direct interviews and online communication

3.4 Sample Size Determination

Sampling is the method used to identify the number of samples and sample unit from a population using statistical method such that it possesses the characteristics of the population. Sampling has been done to identify the sample size and sample units in transportation sector. For proportionally determination of sample size, it was designed with 95% level of confidence with 5% marginal error and 5% non-response rate for the manufacturing industries. The sample size was calculated using Krejci and Morgan formula (Morgan K. , 1970) as indicated below

$$n = \frac{\chi^2 \times p \times q \times N}{e^2\,(N-1) + \chi^2 \times p \times q} \qquad \text{eq. 1}$$

Where,

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

3.5 Data Collection and Compilation

3.5.1 Primary Data

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

3.5.2 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 economic survey reports, energy survey reports, statistical documents, among others.

3.6 Determination of baseline energy demand

The transportation sector's energy consumption was determined using a bottom-up approach. In this method, energy data were gathered from surveys with specific purposes in mind. The collected energy data were then aggregated to determine the specific energy consumption and accordingly the total energy consumption for different fuels used in different vehicles. This approach allowed for a field based energy usage assessment within the transportation sector.

$$\text{Annual Energy Consumption of Vehicles, } E_x = \text{Quantity of fuel per month} \times \text{calorific value} \times \text{number of operating days} \quad \text{eq. 2}$$

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

$$\text{Total energy consumption of vehicles types} = \sum \text{Specific energy consumption} \times \text{no. of vehicles} \quad \text{eq. 4}$$

3.7 Development of Energy Model and Scenarios

3.7.1 Service Demand Projection

The future energy and electricity demand in the transportation sector is based on the service demand projection methodology using two approaches: (i) using population and GDP of the transportation sector in Nepal for road passenger transport sectors, (ii) using GDP only for estimation of service demands in the road freight- transport sub-sectors. The service demand has been calculated using the formula

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

Where,

α1 is elasticity for GVA

α2 is elasticity for population

3.7.2 Development of Scenarios

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.

In this study, the scenario-based projection relies on economic and demographic parameters as the driving factors. The growth in the transportation sector is directly influenced by population growth and gross value added, making these parameters critical for energy projection. By considering these factors, the study aims to create a realistic outlook for energy use, enabling better-informed decision-making to achieve long-term energy sustainability and environmental objectives. Three scenarios with same gross value added with different level of penetration of electric vehicles based on the government targets and policies were developed.

3.7.3 Energy Model Development

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.

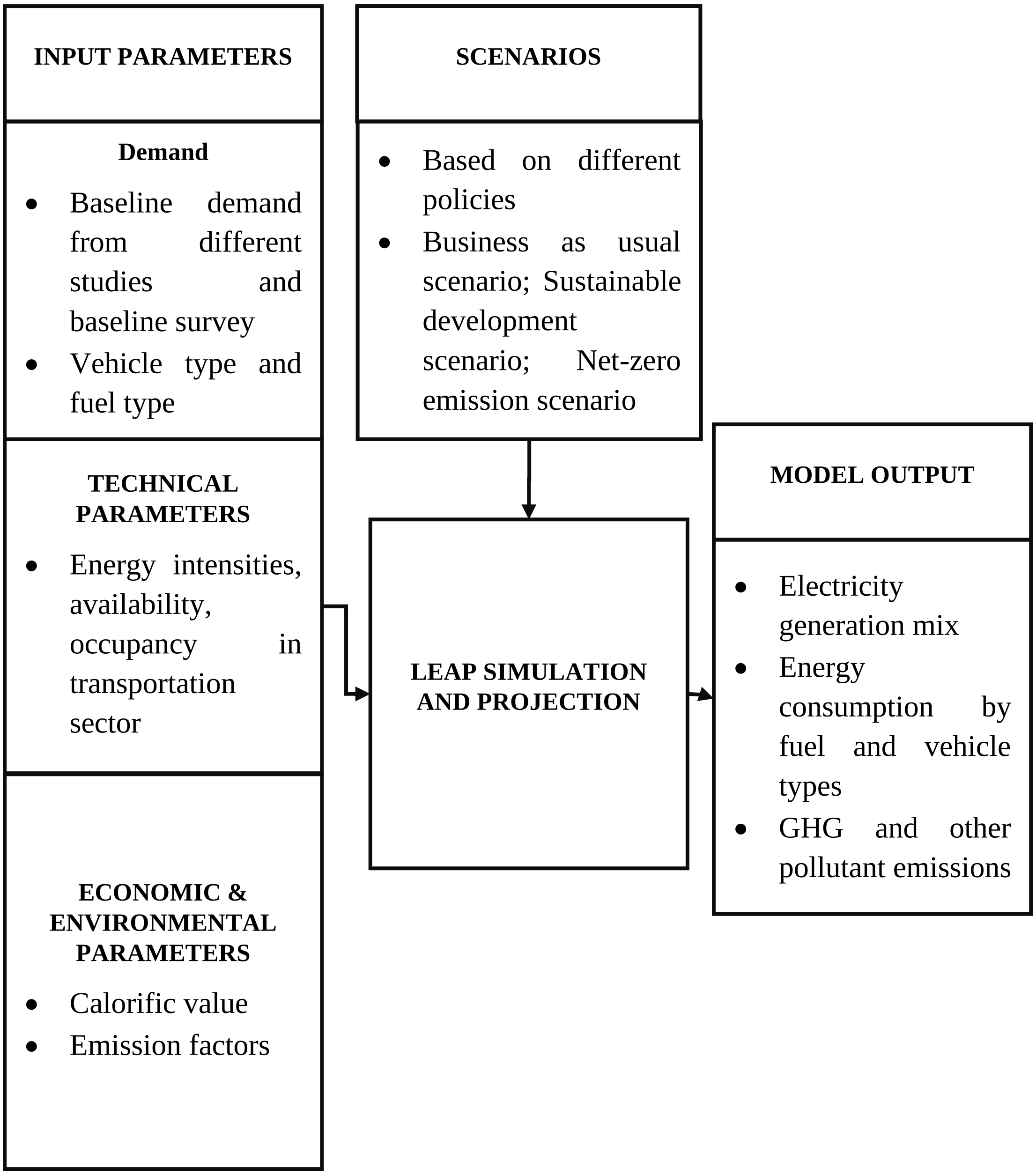


Figure 3-2: LEAP modelling framework

(Handayani et. al., 2022)

3.8 Assessment of electric charging points

In addition to the electricity generation required for the electric vehicles, the infrastructure for electric charging is also necessary. Hence an optimal number of charging points to needed to support the growing electric vehicle has been estimated based on the number of electric vehicles operating in the year.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 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 is considered as the sample. The sample size has been determined using the number of operating vehicles which has further been estimated based on the weighted operating is shown in Table 4-1.

Table 4-1: Vehicles in operation in Nepal (2022/23)

S.N.	Vehicle	Number of vehicles registered	Operating factor	Vehicles in operation
1	Motor cycle	4,266,566	0.55	2,185,269
2	Tempo	92,476	0.48	42,137
3	Car/jeep/Van	322,119	0.40	123,244
4	Micro bus	11,715	0.55	6,280
5	Mini bus	18,740	0.40	6,937
6	Bus	64,647	0.43	27,636
7	Truck/Mini truck	144,501	0.39	53,538
8	Pick up	90,512	0.69	58,852
9	Tractor	184,282	0.49	87,898
10	E rickshaw	55,585	0.15	8,338
	Total	5,251,142	0.54	2,623,114

The overall sample size has been calculated using the Krejcie & Morgan sampling formula considering the population size as 2,623,114 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 404.

Table 4-2:Sample calculation

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	2,623,114
Total sample size	384.05
Non response rate	5%
Total sample size with non-response rate	403.24 ≈ 404

Thus, calculated sample size has been further categorized into different types of vehicles. 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 4-3.

Table 4-3: Samples based on type of vehicles

S.N.	Vehicle	Samples calculated	Actual sample taken
1	Motor cycle	339	340
2	Tempo	7	64
3	Car/jeep/Van	20	70
4	Micro bus	1	33
5	Bus/Minibus	5	11
7	Truck/Mini truck	8	7
8	Pick up	9	10
9	Tractor	14	15
10	E rickshaw	1	5
	Total	404	555

4.2 Status of Transport Sector in Base Year 2022

According to the survey conducted during this study, the total transport sector related energy consumption in Nepal is found to be 64.92 PJ in 2022. The survey revealed that the predominant source of energy consumption was diesel, accounting for 60.48% of the total, followed by petrol at 38.94%. Comparatively, LPG and electricity constituted only 0.46% and 0.11% of the total energy consumption, respectively. The overall energy consumption in the transport sector by fuel types is shown in Figure 4-1.

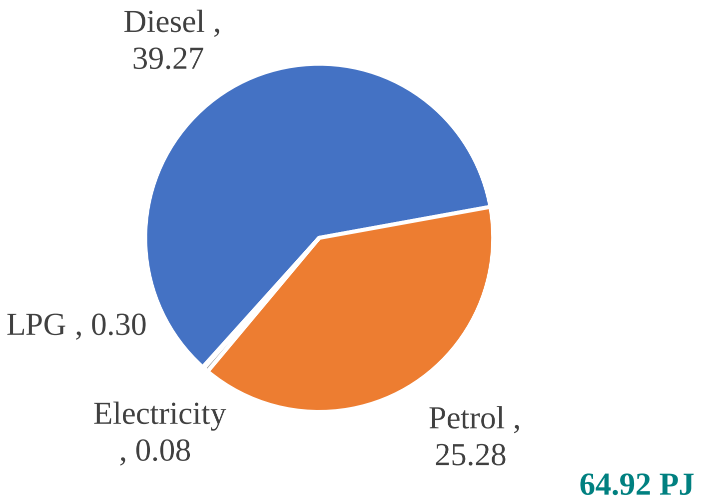


Figure 4-1: Energy Consumption seggregated by fuel type

The amount of fuel consumed in the transportation sector is directly proportional to the energy consumed. The overall diesel consumption in transportation sector in Nepal is 1,035 million litres while that of the petrol is 754 million litres. The amount of different fuels consumed in the transportation sector of Nepal is illustrated in Table 4-4.

Table 4-4 Amount of Fuel Consumption

S.N.	Fuel	Unit	Amount
1.	Diesel	Litres	1,035,248,030
2.	Petrol	Litres	754,854,188
3.	LPG	Litres	9,926,240
4.	Electricity	kWh	19,999,139

According to the study, the energy consumption pattern in the transportation sector reveals that motorcycles have the highest energy consumption, accounting for 30.31% of the total. Tractors come in second place, consuming approximately 19.72% of the energy, followed by trucks/mini trucks at 16.17%, pickups at 11.50%, buses/minibuses at 10.98%, and cars at 7.67%. Additionally, tempos consume around 2.32% of the energy, while microbuses and e-rickshaws consume 1.22% and 0.04%, respectively

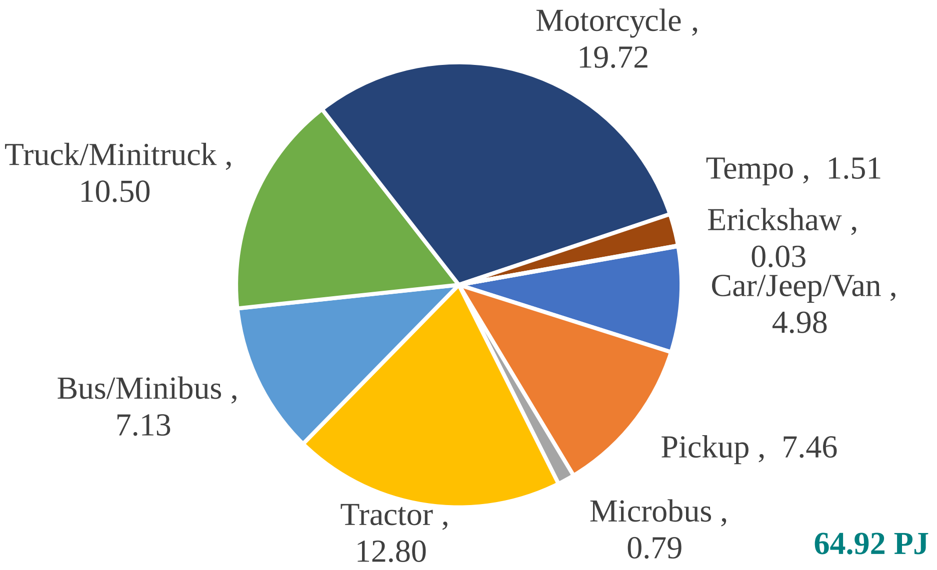


Figure 4-2: Energy Consumption seggregated by vehicle type

4.2.1 Characteristics of Passenger Vehicle

The outcome of the survey indicates that that buses/minibuses have the highest average occupancy of 31.01 passengers, followed by microbuses with 8.47 passengers and tempos with 3.93 passengers. Furthermore, when considering passenger kilometer (pkm), buses/minibuses stand out with 764,663 pkm, followed by microbuses with 224,688 pkm, and tempos with 70,005 pkm. These findings emphasize the substantial utilization of public vehicles highlighting their significance in accommodating higher passenger numbers and contributing to overall transportation efficiency.

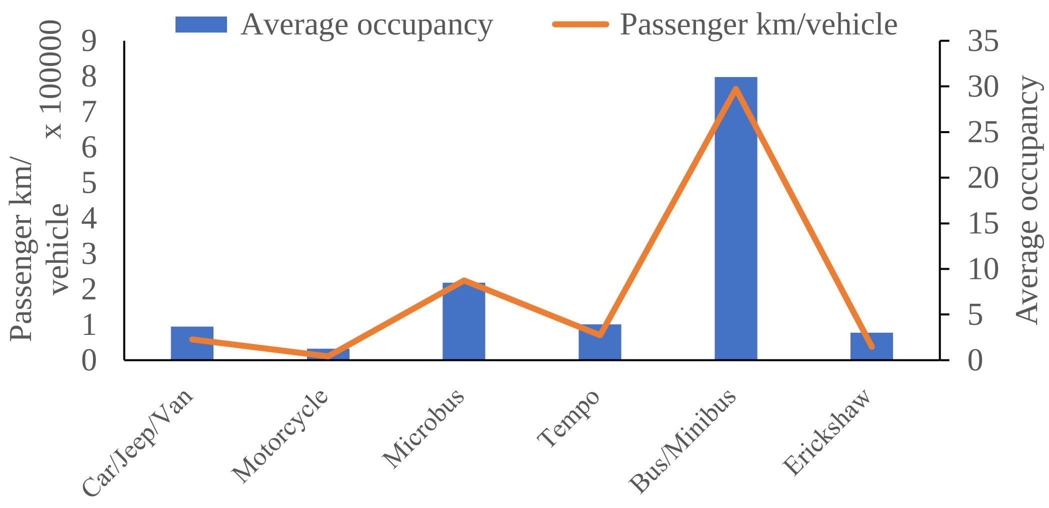


Figure 4-3: Characteristics of passenger vehicle

Similarly, motorcycles have the highest energy consumption per passenger kilometer at 0.76 MJ/pkm, followed by cars/jeeps/vans at 0.66 MJ/pkm, tempos at 52 MJ/pkm, buses/minibuses at 0.48 MJ/pkm, microbuses at 0.27 MJ/pkm, and e-rickshaws at 0.10 MJ/pkm. This indicates that motorcycles have the highest energy consumption per passenger kilometer, indicating that they are less energy-efficient compared to other modes of transportation. On the other hand, micro buses buses/minibuses exhibit lower energy consumption per passenger kilometer, making them more energy-efficient options for transporting passengers. The lower energy per passenger km of the erickshaw indicates the use of energy efficient vehicle rather than energy efficient mode of transportation. The specific energy consumption segregated by fuel types and vehicle type is detailed out in Anex 3

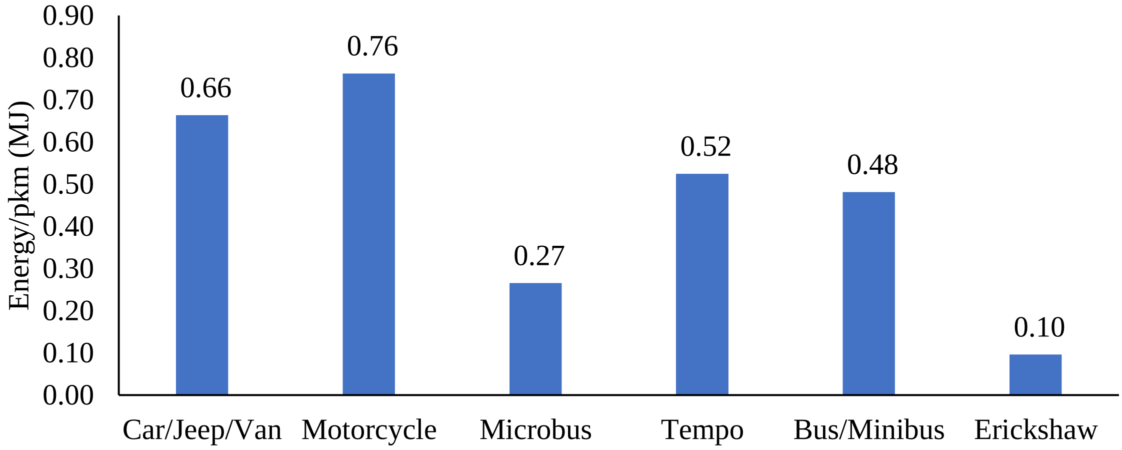


Figure 4-4: Specific energy consumption in passenger vehicles

4.2.2 Characteristics of Freight Vehicle

The outcome of the survey indicates that that on average truck/minitruck carriesaround 6.86 tonnes of load followed by tractor at 1.50 tonnes and pickup at 1.25 tonnes Furthermore, when considering tonne kilometer (tkm), truck stand out with 113,142 tkm followed by pickup with 26,339 tkm, and tractor with 71180 tkm. These results emphasize the significant load-carrying capacity of trucks and their dominance in transporting goods over long distances (as indicated by tkm). Pickups and tractors also play substantial roles in transporting goods, albeit with lesser capacity compared to trucks.

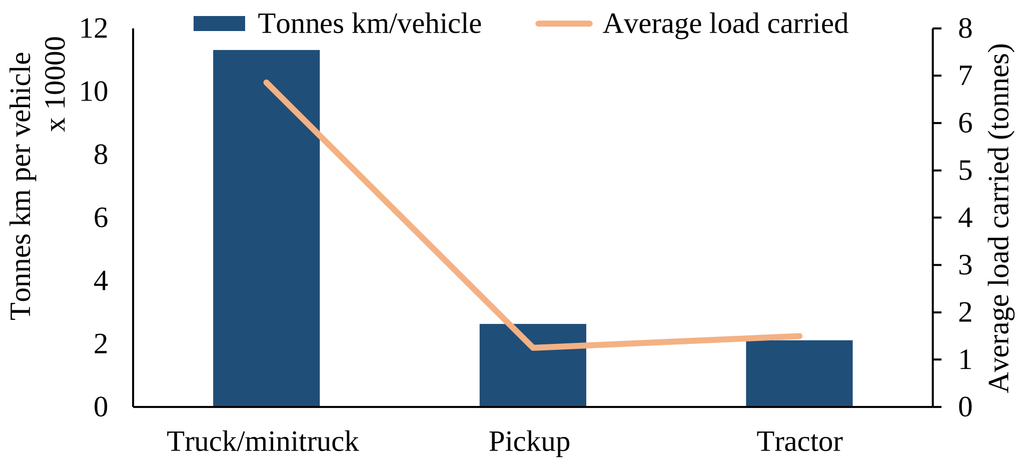


Figure 4-5: Characteristics of freight vehicle

Similarly, tractors have the highest energy consumption per tonnes kilometer at 6.72 MJ/tkm, followed by pickup at 4.54 MJ/tkm and truck/minitruck at 1.65 MJ/tkm. This indicates that tractors have the highest energy consumption per tonnes kilometer, indicating that they are less energy-efficient compared to other modes of freight transportation.

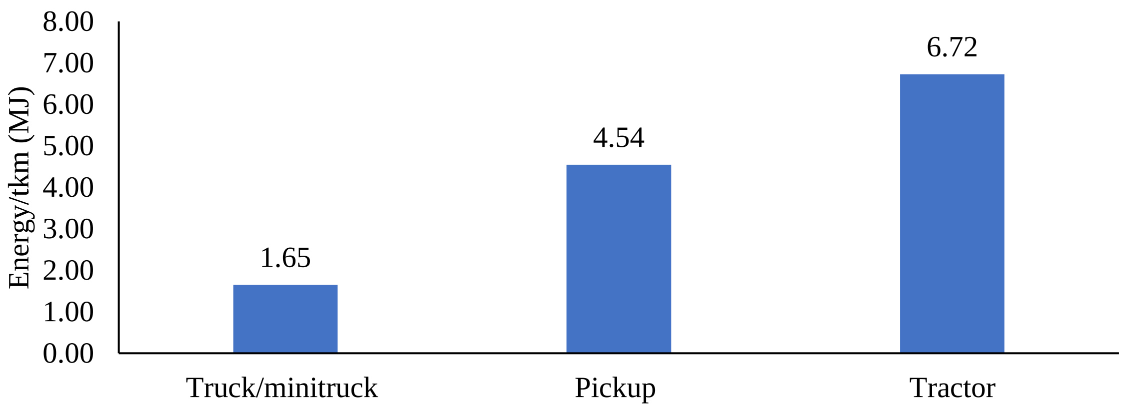


Figure 4-6: Specific energy consumption in freight vehicles

4.3 Scenario Development

In this study three scenarios namely, (i) Business as Usual, (ii) Sustainable Development Scenario and (iii) Net Zero Emission Scenario, have been developed for assessing the energy growth in the transportation sector. The growth rate for the scenarios has been based on the various reports and documents published by the government of Nepal. The population growth rate considered in this study is based on the current population growth rate of Nepal 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, Energy Sector Vision 2050 etc. The details of the growth rate in different scenarios are shown in Table 4-5.

Table 4-5: Population and GDP growth rates for the projection of service demand

Scenario	2022-2025	2025-2030	2030-2035	2035-2040	2040-2045
Population	1.19%	0.93%	0.77%	0.69%	0.56%
Gross Value added	6-7%	7.5%	8%	8.5%	8.3%

It should be noted that the growth rates of population and gross value added for different scenarios are considered to be same in this study. The share of transportation by type and fuel for different scenarios varies according to the various plans and policies. In the business as usual (BAU) scenario, the share of transportation by vehicle type and fuel considered in this study is based on the historical trends in Nepal, whereas in the sustainable development scenario, the share of vehicle is based on the targets of the Second Nationally Determined Contribution (NDC) and in the net zero emission scenario, the vehicle is based on the Long-Term Scenario for Net Zero Emission.

4.4 Energy Projection

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 2045. For the base year, the energy model was developed based on the data collected and analyzed.

4.5 Business as Usual Scenario

4.5.1 Total Energy Consumption

The business as usual (BAU) scenario has been developed based on the historical trend of fuels used in different vehicles in Nepal. The energy consumption in this scenario has been forecasted to reach 92.41 PJ by 2030 and 180.46 PJ by 2045. The energy demand CAGR in this scenario is projected to be 4.55%. The total energy consumptions for different years are shown in Figure 4-7.

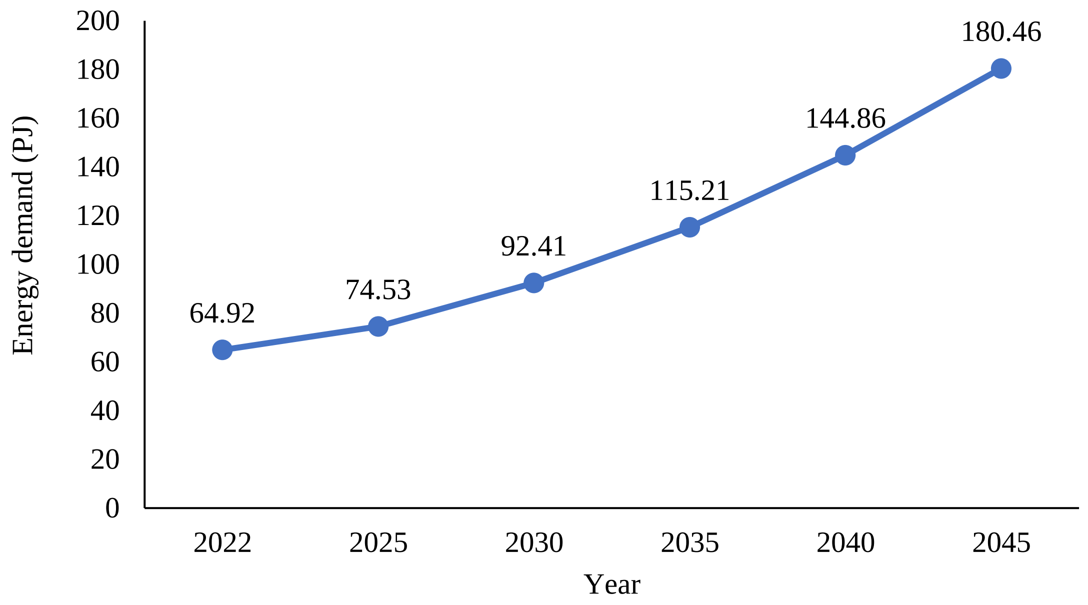


Figure 4-7: Energy consumption for busieness as usual scenario

4.5.2 Energy Consumption 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 the Business as Usual (BAU) scenario, the demand for petroleum products, specifically diesel and petrol, is projected increase at a growth rate of 4.61% and 4.41%, respectively. On the other hand, the demand of electricity as a transportation fuel is expected to grow at a faster rate of 9.93%. The overall energy consumption by fuel type is shown in Table 4-6. This implies that while the demand for electricity as a fuel source will rise, petrol and diesel will continue to maintain their dominant position as the primary fuels in the transportation sector.

Table 4-6: Energy projection by fuel type (PJ)

Fuel	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Electricity	0.07	0.15	0.22	0.32	0.46	0.64
Petrol	25.28	29.59	36.57	45.12	55.86	68.25
Diesel	39.27	44.44	55.18	69.23	87.87	110.75
LPG	0.30	0.35	0.44	0.54	0.67	0.82
Total	**64.92**	**74.53**	**92.41**	**115.21**	**144.86**	**180.46**

With the change in the consumption pattern, the energy mix in the transportation sector in Nepal will also change. In 2022, petrol accounted for 38.94% and diesel for 60.49% of the mix while the share of petrol and diesel in the 2030 is forecasted to become 39.57% and 59.71% Similarly, the share of petrol and diesel in 2045 will reach 37.82% and 61.37% respectively. The energy mix of different fuels in the 2022 is shown in Figure 4-8 while that in 2030 and 2045 is shown in Figure 4-9.

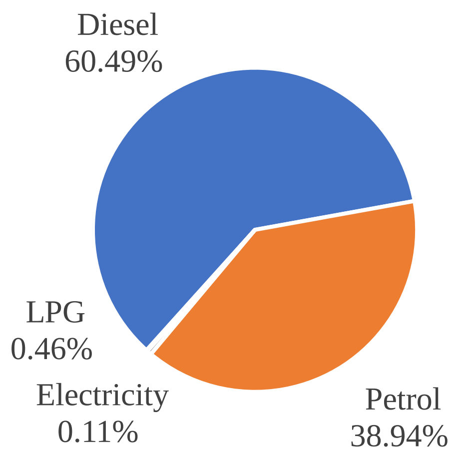


Figure 4-8: Energy mix for 2022 (in PJ)

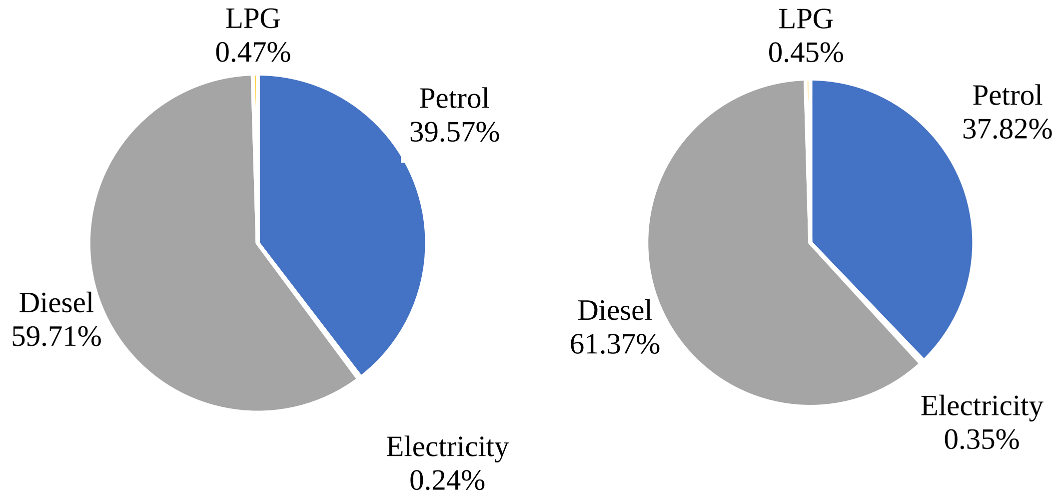


Figure 4-9: Energy mix for 2030 (left) and 2045 (right) (in PJ)

4.5.3 Energy Consumption by Vehicle type

Over the forecasted timeframe, motorcycles will continue to dominate energy consumption, with anticipated energy demand reaching 28.66 PJ by 2030 and 53.71 PJ by 2045. Similarly, tractors are projected to exhibit an energy demand of 17.81 PJ by 2030 and 36.40 PJ by 2045. Moreover, the energy demand for trucks/minitrucks is estimated to be 14.61 PJ by 2030 and 29.86 PJ by 2045, while pickups are expected to require 10.39 PJ by 2030 and 21.23 PJ by 2045. Additionally, buses/minibuses are anticipated to manifest an energy demand of 10.39 PJ by 2030 and 19.58 PJ by 2045, and cars are predicted to reach 7.16 PJ by 2030 and 13.28 PJ by 2045. The energy demand of different vehicles in the BAU scenario is shown in Table 4-7.

Table 4-7: Energy demand by vehicle type (PJ)

Vehicle	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Car/Jeep/Van	4.98	5.80	7.16	8.82	10.89	13.28
Motorcycle	19.72	23.15	28.66	35.41	43.90	53.71
Tempo	1.51	1.77	2.20	2.72	3.38	4.14
Microbus	0.79	0.94	1.16	1.44	1.78	2.19
Bus/Minibus	7.13	8.38	10.39	12.87	15.98	19.58
Erickshaw	0.02	0.03	0.03	0.04	0.05	0.07
Truck/Minitruck	10.50	11.76	14.61	18.40	23.51	29.86
Tractor	12.80	14.34	17.81	22.44	28.66	36.40
Pickup	7.46	8.36	10.39	13.08	16.71	21.23
Total	**64.92**	**74.53**	**92.41**	**115.21**	**144.86**	**180.46**

4.5.4 Greenhouse Gases Emission

The GHG emission in the base year for the transportation sector is estimated to be 4.09 mMTCO$_{2eq}$ at 100 year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 4.45% until 2030. Following this period, the emissions are expected to continue increasing at a slightly higher rate of 4.56% until the year 2045. The overall GHG emission in the BAU scenario is shown in Table 4-8.

Table 4-8: GHG emissions from transportation sector (mMTCO$_{2eq}$)

GHG	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Carbon dioxide (CO_2)	3.95	4.52	5.60	6.99	8.81	11.00
Methane (CH_4)	0.08	0.10	0.12	0.15	0.18	0.22
Nitrous Oxide (N_2O)	0.06	0.07	0.09	0.11	0.14	0.17
Total	**4.10**	**4.68**	**5.81**	**7.25**	**9.13**	**11.39**

4.6 Sustainable Development Scenario

The energy consumption in the sustainable development scenario has been forecasted based on the commitments of the second NDC of Nepal. The major assumptions during the scenario are:

- Sales of electric motorcycle will reach 25% of all motor cycle sales by 2025 and 90% by 2030
- Sales of electric car/jeep/van will reach 25% of all car/jeep/van sales by 2025 and 90% by 2030
- Sales of electric buses and microbus will reach 20% and 60% of all sales by 2025 and 2030 respectively
- LPG will be phased out by 2035
- The electricity shall penetrate in the freight vehicles after 2030 and the share of electric freight vehicle will reach around 5% by 2045

4.6.1 Total Energy Consumption

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 NDC. The energy consumption in this scenario has been forecasted to reach 68.35 PJ by 2030 and 89.58 PJ by 2045. The energy demand CAGR in this scenario is projected to be 2.19%. The total energy consumptions for different years are shown in Figure 4-7.

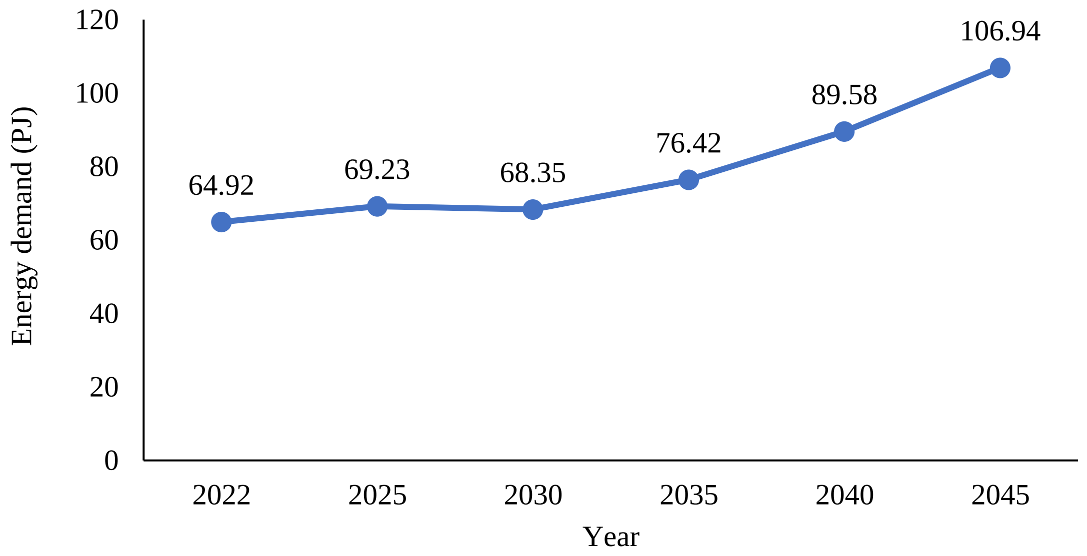


Figure 4-10: Energy consumption for busieness as usual scenario

4.6.2 Energy Consumption by Fuel Type

In the context of sustainable development, the demand for diesel is expected to rise at a CAGR of 3.6%, while petrol has been projected to decline by 11.9%, with LPG being phased out entirely by 2035. In contrast, electricity as a transportation fuel is anticipated to experience a significant growth at a CAGR of 26.68% as shown in Table 4-9.. This increase in electricity demand and simultaneous decrease in petrol and LPG consumption can be attributed to the widespread adoption of electric vehicles.

Table 4-9: Energy projection by fuel type (PJ)

Fuel	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Electricity	0.07	1.30	5.45	8.75	12.42	16.60
Petrol	25.28	24.58	13.33	8.84	4.80	1.36
Diesel	39.27	43.08	49.41	58.83	72.36	88.98
LPG	0.30	0.27	0.17	-	-	-
Total	64.92	69.23	68.35	76.42	89.58	106.94

In 2022, petrol accounted for 38.94% and diesel for 60.49% of the mix while the share of petrol, diesel and electricity in the 2030 is forecasted to become 11.57%, 76.98% and 11.45%. Similarly, the share of petrol, diesel and electricity in 2045 will reach 83.21%, 1.27% and 15.52% respectively. The energy mix of different fuels in the year 2022, 2030 and 2045 is shown in Figure 4-11 and Figure 4-12 respectively.

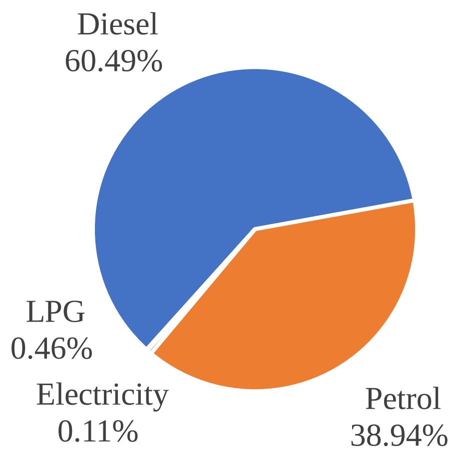


Figure 4-11: Energy mix for 2022 (in PJ)

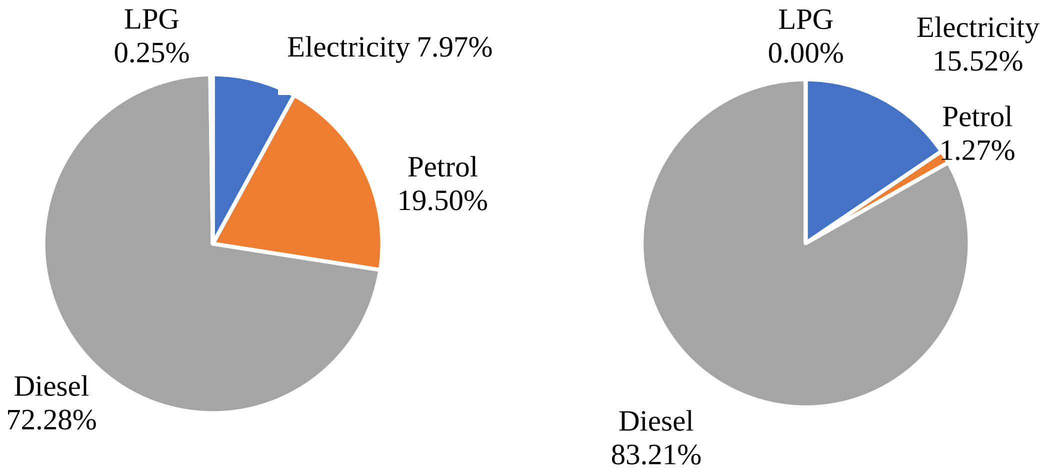


Figure 4-12: Energy mix for 2030 (left) and 2045 (right) (in PJ)

4.6.3 Energy Consumption by Vehicle type

The energy consumption of cars, jeeps, and vans is expected to surpass that of motorcycles in this scenario by 2040. The anticipated energy demand for motorcycles and cars/jeeps/vans is estimated to reach 10.48 PJ and 5.05 PJ, respectively, by 2030, and 2.79 PJ and 7.45 PJ by 2045. Similarly, tractors are projected to exhibit an energy demand of 17.81 PJ by 2030 and 34.94 PJ by 2045. Moreover, the energy demand for trucks/minitrucks is estimated to be 14.61 PJ by 2030 and 28.81 PJ by 2045, while pickups are expected to require 10.39 PJ by 2030 and 20.28 PJ by 2045. Additionally, buses/minibuses are anticipated to increase energy demand of 8.39 PJ by 2030 and 10.95 PJ by 2045. The energy demand of different vehicles in the BAU scenario is shown in Table 4-10.

Table 4-10: Energy demand by vehicle type (PJ)

Vehicle	2022	2025	2030	2035	2040	2045
Car/Jeep/Van	4.98	5.34	5.05	5.45	6.35	7.45
Motorcycle	19.72	19.00	10.48	6.94	4.41	2.79
Tempo	1.51	1.82	1.65	1.66	1.26	0.57
Microbus	0.79	0.89	0.83	0.88	0.97	1.09
Bus/Minibus	7.13	7.69	7.50	8.23	9.46	10.95
E rickshaw	0.02	0.03	0.03	0.04	0.05	0.07
Truck/minitruck	10.50	11.76	14.61	18.19	22.96	28.81
Tractor	12.80	14.34	17.81	22.14	27.89	34.94

Vehicle	2022	2025	2030	2035	2040	2045
Pickup	7.46	8.36	10.39	12.89	16.21	20.28
Total	**64.92**	**69.23**	**68.35**	**76.42**	**89.58**	**106.94**

4.6.4 Greenhouse Gases Emission

The GHG emission in the base year for the transportation sector is estimated to be 4.09 $mMTCO_{2eq}$ at 100 year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 0.51% until 2030. Following this period, the emissions are expected to continue increasing at a slightly higher rate of 2.90 % until the year 2045. This data illustrates a rising penetration rate of electricity in the transportation sector until 2030. However, the rate is expected to decline thereafter as most of the of private car/jeep/van and motorcycle are electricity by 2030 The overall GHG emission in the SD scenario is shown in Table 4-11.

Table 4-11: GHG emissions from transportation sector ($mMTCO_{2eq}$)

GHG	2022	2025	2030	2035	2040	2045
Carbon dioxide (CO_2)	3.95	4.20	4.16	4.64	5.42	6.44
Methane (CH_4)	0.08	0.08	0.05	0.03	0.02	0.02
Nitrous Oxide (N_2O)	0.06	0.07	0.06	0.07	0.08	0.09
Total	4.10	4.35	4.27	4.74	5.52	6.55

4.7 Net-Zero Emission 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:

- All the passenger vehicles shall shift to electricity by 2045
- All the freight vehicles shall shift to electricity by 2045

4.7.1 Total Energy Consumption

The Net-zero emission (NZE) scenario has been developed based on the net zero emission targets from transportation sector by 2045 The energy consumption in this scenario has been forecasted to reach 70.27 PJ by 2030 and then decrease thereafter to 36.94 PJ by 2045. The energy demand CAGR in this scenario will be -2.42%. The total energy consumptions for different years are shown in Figure 4-13.

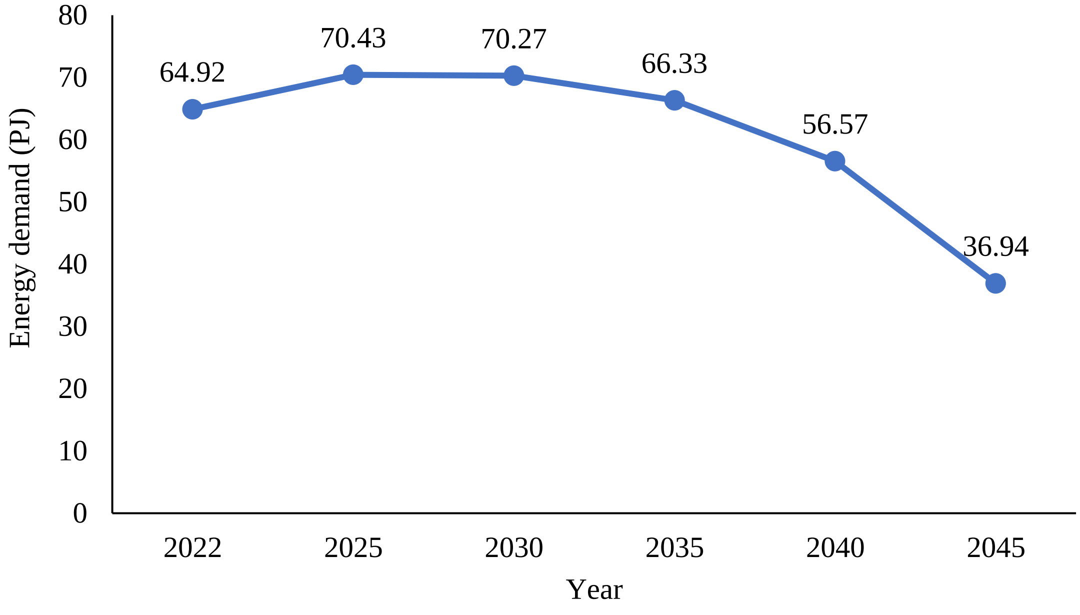


Figure 4-13: Energy consumption for Net-zero emission scenario

4.7.2 Energy Consumption 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 the net zero emission scenario, the demand for petroleum products is projected too phase out by 2045. On the other hand, the demand of electricity as a transportation fuel is expected to grow at a faster rate of 31.12%. The overall energy consumption by fuel type is shown in Table 4-12.

Table 4-12: Energy projection by fuel type (PJ)

Fuel	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Electricity	0.07	1.11	5.74	12.61	22.74	36.94
Petrol	25.28	25.86	24.05	19.84	12.32	-
Diesel	39.27	43.15	40.19	33.63	21.36	-
LPG	0.30	0.31	0.28	0.23	0.15	-
Total	64.92	70.43	70.27	66.33	56.57	36.94

In 2022, petrol accounted for 38.94% and diesel for 60.49% of the mix while the share of petrol and diesel in the 2030 is forecasted to become 39.57% and 59.71%. Similarly, the share of petrol and diesel in 2045 will reach 37.82% and 61.37% respectively. the energy mix in 2022, 2030 and 2045 is shown in Figure 4-14 and Figure 4-15.

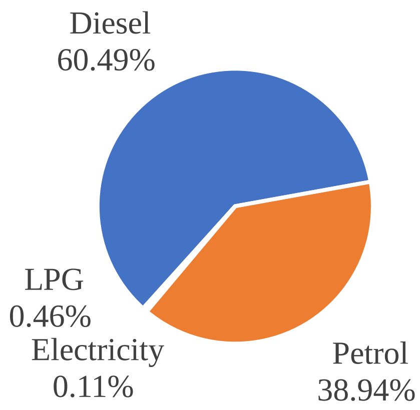


Figure 4-14: Energy mix for 2022 (in PJ)

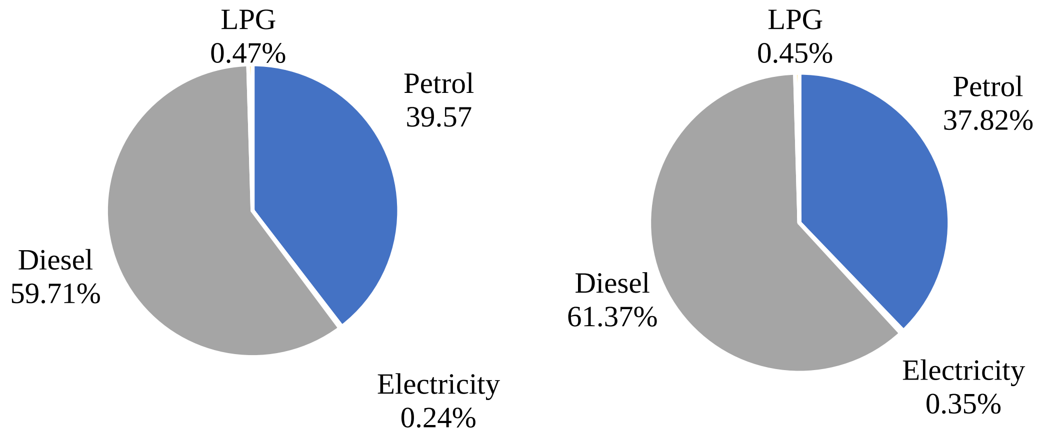


Figure 4-15: Energy mix for 2030 (left) and 2045 (right) (in PJ)

4.7.3 Energy Consumption by Vehicle type

The energy consumption of cars, jeeps, and vans is expected to surpass that of motorcycles in this scenario by 2040. The anticipated energy demand for motorcycles and cars/jeeps/vans is estimated to reach 19.28 PJ and 6.02 PJ, respectively, by 2030, and 2.79 PJ and 6.96 PJ by 2045. Similarly, tractors are projected to exhibit an energy demand of 14.25 PJ by 2030 and 7.25 PJ by 2045. Moreover, the energy demand for trucks/minitrucks is estimated to be 12.04 PJ by 2030 and 8.88 PJ by 2045, while pickups are expected to require 8.07 PJ by 2030 and 2.29 PJ by 2045. Additionally, buses/minibuses are anticipated to increase energy demand of 8.22 PJ by 2030 and 7.79 PJ by 2045. The energy demand of different vehicles in the BAU scenario is shown in Table 4-13.

Table 4-13: Energy demand by vehicle type (PJ)

Vehicle	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Car/Jeep/Van	4.98	5.48	6.02	6.49	6.87	6.96
Motorcycle	19.72	20.33	19.28	16.52	11.39	2.79
Tempo	1.51	1.56	1.48	1.29	0.91	0.28
Microbus	0.79	0.85	0.87	0.86	0.79	0.63
Bus/Minibus	7.13	7.73	8.22	8.49	8.45	7.79
Erickshaw	0.02	0.03	0.03	0.04	0.05	0.07
Truck/Minitruck	10.50	11.76	12.04	11.94	11.12	8.88
Tractor	12.80	14.34	14.25	13.45	11.45	7.25
Pickup	7.46	8.36	8.07	7.25	5.53	2.29
Total	**64.92**	**70.43**	**70.27**	**66.33**	**56.57**	**36.94**

4.7.4 Green House Gases Emission

The GHG emission in the base year for the transportation sector is estimated to be 4.09 $mMTCO_{2eq}$ at 100 year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 0.03% until 2030. Following this period, the emissions are expected to continue to decrease and become net zero by 2045. The overall GHG emission in NZE scenario is shown in Table 4-14.

Table 4-14: GHG emissions from transportation sector ($mMTCO_{2eq}$)

GHG	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Carbon dioxide (CO_2)	3.95	4.26	3.96	3.30	2.09	-
Methane (CH_4)	0.08	0.08	0.08	0.06	0.04	-
Nitrous Oxide (N_2O)	0.06	0.07	0.06	0.05	0.03	-
Total	**4.10**	**4.41**	**4.10**	**3.42**	**2.16**	**-**

4.8 Electricity Generation Requirement

4.8.1 Electricity Demand by Transportation Sector

The sustainable development scenario and the net zero emission scenario consider large penetration of the electric vehicle while the business of usual scenario considers the historical trend i.e small penetration of electric vehicles, as shown in the Table 4-15.

The consumption of electrical energy is expected to increase continuously at a rate of 9.93%, 26.68% and 31.17% in the business as usual, sustainable development and the net-zero emission scenario. The electricity demand and power plant capacity required to supply the electricity under the assumption that the generated electricity is utilized throughout the day is shown in Table 4-15.

Table 4-15: Electricity demand and power plant capacity

Scenario	2025	2030	2035	2040	2045
Energy demand in GWh					
Business as usual	40.92	61.53	89.49	127.65	176.62
Sustainable development	361.54	1,513.80	2,430.84	3,449.96	4,609.78
Net-zero emission	308.12	1,595.23	3,503.53	6,316.58	10,261.72
Power Plant Capacity in MW					
Business as usual	6.74	10.13	14.74	21.02	29.09
Sustainable development	59.54	249.31	400.34	568.18	759.19
Net-zero emission	50.74	262.72	577.00	1,040.28	1,690.01

4.8.2 Electric Vehicles in Nepal

The number of electric vehicles plays a major role in determining the number of charging stations required. Based on the electricity requirement in three different scenarios and on the assumptions that the characteristics of different vehicle remains same, number of electric vehicle (except freight vehicles) has been presented in Table 4-16.

Table 4-16: Number of electric vehicles in Nepal

Vehicle type	2025	2030	2035	2040	2045
Business as Usual					
Car/Jeep/Van	4,509	7,446	11,505	17,124	24,453
Motorcycle	14,521	23,977	37,049	55,144	78,746
Tempo	3,277	4,063	5,029	6,245	7,653
Microbus	420	520	644	800	980
Bus/minibus	45	56	69	86	106
E Rickshaw	9,823	12,179	15,074	18,720	22,942
Total	32,595	48,241	69,371	98,120	134,880
Sustainable Development Scenario					

Vehicle type	2025	2030	2035	2040	2045
Car/Jeep/Van	27,541	117,728	181,881	250,405	326,523
Motorcycle	539,562	2,325,073	3,641,413	5,054,133	6,526,011
Tempo	3,906	25,668	47,123	80,298	125,028
Microbus	973	4,256	7,000	10,023	13,434
Bus/minibus	5,728	23,754	37,962	53,405	70,708
E Rickshaw	9,823	12,179	15,074	18,720	22,942
Total	587,532	2,508,659	3,930,452	5,466,984	7,084,646
Net Zero Emission Scenario					
Car/Jeep/Van	21,198	66,879	133,020	227,590	355,380
Motorcycle	371,372	1,211,494	2,428,983	4,170,828	6,526,011
Tempo	10,272	27,192	51,548	86,235	132,910
Microbus	1,400	3,761	7,161	12,006	18,527
Bus/minibus	5,430	17,859	35,875	61,654	96,516
E Rickshaw	9,823	12,179	15,074	18,720	22,942
Total	419,494	1,339,364	2,671,661	4,577,033	7,152,286

Similarly, to study the impact of the penetration of public transportation vehicles, such as buses and minibuses, on the overarching problem of traffic congestion in Net zero scenario, an assessment has been undertaken to evaluate the reduction in the overall vehicular count. This analysis explicitly contemplates a situation in which buses and minibuses cater to 75% of the total passenger kilometers. This will reduce the total number of vehicles by 56%.

Table 4-17: Electric vehicle with 75% passenger demand due to Bus/minibus in NZE scenario

Vehicle type	2025	2030	2035	2040	2045
Car/Jeep/Van	21,150	57,149	94,617	129,290	150,989
Motorcycle	371,053	1,036,518	1,729,441	2,370,840	2,772,676
Tempo	10,263	23,265	36,702	49,019	56,469
Microbus	1,398	3,217	5,099	6,824	7,872
Bus/minibus	5,427	21,507	50,548	99,492	175,509
E Rickshaw	12,033	12,776	13,160	13,047	11,951
Total	421,324	1,154,433	1,929,566	2,668,513	3,175,466

4.9 Demand of Charging Stations

Demand of charging stations depend upon the number of electric vehicles in operation along with its penetration level and utilization patterns. Similarly the charging requirement for different type of vehicle varies while 15A single phase supply is sufficient for the charging of motorcycles, tempo and e-rickshaw, three phase supply either 22 kW AC or 60 kW DC is necessary for the car/jeep/van as shown in Table 4-18.

Table 4-18: Charging requirements for electric vehicles

Vehicle Type	Charging requirements
Car/Jeep/Van	Type-2 AC (22kW) or CCS 2.0 (60kW)
Motorcycle	Single Phase 15A
Tempo	Single Phase 15A
Microbus	Type-2 AC (22kW) or DC (60kW)
Bus minibus	DC (500 kW)
E rickshaw	Single Phase 15A

Further it is also important to identify the share of electric vehicle that shall be charged at public charging stations since most of the personal electric vehicle may fulfill its charging requirement at homes/office. According to the Handbook for EV Charging, 2021 it has been recommended to consider public charging for 10% of electric motorcycle, e-rickshaw & tempo and 10%-25% of car/jeep/van (Niti Aayog,2021). Based on the following consideration the number of charging station at 25% of utilization in different scenarios is shown in Table 4-19.

Table 4-19: Number of charging points

Vehicle	Electricity demand in GWh		Share of Public Charging	Number of Chargers	
	2030	2045		2030	2045
Business As Usual Scenario					
Car/Jeep/Van	40.51	133.04	10.00%	46.00	149.00
Motorcycle	2.84	9.34	17.50%	66.00	217.00
Tempo	2.34	4.40	20.00%	62.00	117.00
Microbus	4.94	9.31	25.00%	14.00	26.00

Vehicle	Electricity demand in GWh		Share of Public Charging	Number of Chargers	
	2030	2045		2030	2045
Bus/minibus	1.26	2.37	50.00%	2.00	3.00
E Rickshaw	9.65	18.17	20.00%	256.00	481.00
Sustainable Development Scenario					
Car/Jeep/Van	640.51	1,776.47	10.00%	714.00	1,979.00
Motorcycle	275.68	773.79	17.50%	6,386.00	17,923.00
Tempo	14.77	71.94	20.00%	391.00	1,905.00
Microbus	40.41	127.56	25.00%	113.00	356.00
Bus/minibus	532.78	1,585.89	50.00%	609.00	1,811.00
E Rickshaw	9.65	18.17	20.00%	256.00	481.00
Net Zero Emission Scenario					
Car/Jeep/Van	363.86	1,933.47	10.00%	406.00	2,154.00
Motorcycle	143.65	773.79	17.50%	3,328.00	17,923.00
Tempo	15.65	76.48	20.00%	415.00	2,025.00
Microbus	35.71	175.92	25.00%	100.00	490.00
Bus/minibus	400.55	2,164.74	50.00%	458.00	2,472.00
E Rickshaw	9.65	18.17	20.00%	256.00	481.00

Similarly, if 75% passenger demand is fulfilled by bus/minibus under similar condition the number of charging points required to fulfill the charging requirement will decrease by 44%. The detail of the charging point is shown in Table 4-20.

Table 4-20: Charging point with 75% passenger demand is due to bus/minibus (NZE scenario)

Vehicle type	**2025**	**2030**	**2035**	**2040**	**2045**
Car/Jeep/Van	21,150	57,149	94,617	129,290	150,989
Motorcycle	371,053	1,036,518	1,729,441	2,370,840	2,772,676
Tempo	10,263	23,265	36,702	49,019	56,469
Microbus	1,398	3,217	5,099	6,824	7,872
Bus/minibus	5,427	21,507	50,548	99,492	175,509
E Rickshaw	12,033	12,776	13,160	13,047	11,951
Total	421,324	1,154,433	1,929,566	2,668,513	3,175,466

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Following conclusion has been drawn from the study are as follow:

- The total energy consumption in transportation sector Nepal in 2022 is found to be 64.92 PJ out of which the diesel accounts for 60.48% followed by petrol, diesel, LPG and electricity at 60.48%, 38.94%, 0.46% and 0.11%. In regards to the vehicle type motorcycle consumed 30.31% followed by tractors' at 19.72% of the energy, followed by trucks/mini trucks at 16.17%, pickups at 11.50%, buses/minibuses at 10.98%, and cars at 7.67%
- The energy demand is projected to increase at a compounded annual growth rate of 4.55% in business as usual scenario and reach 180.46 PJ by 2045 whereas in the sustainable development scenario the energy demand will increase at 2.19% and reach 106.94 PJ and in the net zero emission scenario the energy demand will increase at a CAGR of -2.42% and reach 36.94 PJ by 2045.
- The electricity demand to support the growing number of electric vehicles is projected to reach 176.62 GWh, 4,609.78 GWh, and 10,261.72 GWh by the year 2045 under the business as usual scenario, sustainable development scenario, and net-zero emission scenario, respectively. Additionally, the corresponding power plant capacities required in these scenarios are anticipated to be 29.09 MW, 759.19 MW, and 1,690.01 MW by 2045
- The number of passenger electric vehicle in Nepal will reach 134,880, 7,084,646, 7,152,286 by 2045 in the business-as-usual scenario, sustainable development scenario and net zero emission scenario. Under the net zero emission scenario if the 75% passenger demand is fulfilled by the bus/minibus, the number of electric vehicle by 2045 will reduce by 56%.
- The number of charging points in the business as usual scenario, sustainable development scenario and net zero scenario required to sustain the increasing demand of electric vehicle will reach 993, 24,455 and 25,545 by 2045 respectively

5.2 Recommendations

Following recommendations have been made from the study:

- The increasing number of vehicles will create huge traffic congestion and hence the mass transportation should be promoted
- In order to achieve the targets of the second national determined contribution and long term strategy for net zero emission the number off electric vehicles should be drastically improved
- The number of powerplants should be increased as the number of electric vehicle has the potential to rapidly increase the electricity demand.

5.3 Future Research Area

This research study represents energy demand projection of transportation sector as a result of mass adoption of electric vehicle. Building on the study the optimal placement of the charging station along with the impact of electric vehicles on the distribution and transmission system can be studied. Similarly, the penetration of hydrogen fuel and other upcoming vehicles can also be incorporated in the study.

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ANNEXES

Annex 1: Questionnaire for field survey

Date:

Information about respondent and location

Name of respondent:		Contact no:	
Age:……………	Ethnicity …………………………	Gender	☐ Male ☐ Female ☐ Others
District :		Municipality/Rural Municipality:	
Ward number:		Average monthly income	

General Information of the vehicle

Question	Description	
Owner of the vehicle		
Contact of the owner		
Vehicle number Plate		
Vehicle ownership type	○ Personal ○ Institutional (private corporate/government/embassy) ○ Public (local/short distance) ○ Public (long distance) ○ Freight	
Vehicle	If Passenger	If Freight
	○ Bus ○ Minibus ○ Microbus ○ Car ○ Jeep ○ Van ○ Tempo ○ E-rickshaw ○ Motorcycle ○ Others	○ Lorry ○ Truck ○ mini truck ○ pickup ○ tractor ○ Cargo van ○ Others
Engine capacity		c.c.
		Watt (for electric vehicle)
Type of fuel used	○ Petrol ○ Diesel ○ LP gas ○ Electricity ○ Others	
Vehicle capacity		Persons (if passenger)
		Tons (if freight)

Annex 2: Fuel Wise Energy Consumption in Different vehicles

A. Business as usual scenario (PJ)

Branch	2022	2025	2030	2035	2040	2045
Passenger	**34.15**	**40.07**	**49.60**	**61.29**	**75.99**	**92.97**
Car/Jeep/Van	**4.98**	**5.80**	**7.16**	**8.82**	**10.89**	**13.28**
Electricity	0.03	0.09	0.15	0.23	0.34	0.48
Petrol	4.35	5.02	6.16	7.55	9.28	11.25
Diesel	0.60	0.69	0.85	1.04	1.28	1.55
Motorcycle	**19.72**	**23.15**	**28.66**	**35.41**	**43.90**	**53.71**
Electricity	0.00	0.01	0.01	0.02	0.02	0.03
Petrol	19.72	23.14	28.65	35.39	43.88	53.68
Tempo	**1.51**	**1.77**	**2.20**	**2.72**	**3.38**	**4.14**
Electricity	0.01	0.01	0.01	0.01	0.01	0.02
LPG	0.29	0.35	0.43	0.53	0.66	0.81
Petrol	1.21	1.42	1.76	2.18	2.71	3.32
Microbus	**0.79**	**0.94**	**1.16**	**1.44**	**1.78**	**2.19**
Diesel	0.78	0.92	1.14	1.41	1.75	2.14
LPG	0.01	0.01	0.01	0.01	0.01	0.01
Electricity	0.01	0.01	0.02	0.02	0.03	0.03
Bus minibus	**7.13**	**8.38**	**10.39**	**12.87**	**15.98**	**19.58**
Electricity	0.00	0.00	0.00	0.01	0.01	0.01
Diesel	7.12	8.38	10.39	12.86	15.97	19.57
E rickshaw	**0.02**	**0.03**	**0.03**	**0.04**	**0.05**	**0.07**
Electricity	0.02	0.03	0.03	0.04	0.05	0.07
Frieght	**30.76**	**34.46**	**42.81**	**53.92**	**68.88**	**87.49**
Truck/minitruck	**10.50**	**11.76**	**14.61**	**18.40**	**23.51**	**29.86**
Diesel	10.50	11.76	14.61	18.40	23.51	29.86
Electricity	-	-	-	-	-	-
Tractor	**12.80**	**14.34**	**17.81**	**22.44**	**28.66**	**36.40**
Diesel	12.80	14.34	17.81	22.44	28.66	36.40
Electricity	-	-	-	-	-	-

Branch	2022	2025	2030	2035	2040	2045
Pickup	**7.46**	**8.36**	**10.39**	**13.08**	**16.71**	**21.23**
Diesel	7.46	8.36	10.39	13.08	16.71	21.23
Electricity	-	-	-	-	-	-
Total	**64.92**	**74.53**	**92.41**	**115.21**	**144.86**	**180.46**

B. Sustainable Development Scenario (PJ)

Branch	2022	2025	2030	2035	2040	2045
Passenger	**34.15**	**34.77**	**25.54**	**23.21**	**22.51**	**22.91**
Car/Jeep/Van	**4.98**	**5.34**	**5.05**	**5.45**	**6.35**	**7.45**
Electricity	0.03	0.54	2.31	3.56	4.90	6.40
Petrol	4.35	4.26	2.41	1.89	1.45	1.06
Diesel	0.60	0.54	0.34	-	-	-
Motorcycle	**19.72**	**19.00**	**10.48**	**6.94**	**4.41**	**2.79**
Electricity	0.00	0.23	0.99	1.55	2.16	2.79
Petrol	19.72	18.77	9.49	5.38	2.26	-
Tempo	**1.51**	**1.82**	**1.65**	**1.66**	**1.26**	**0.57**
Electricity	0.01	0.01	0.05	0.10	0.17	0.26
LPG	0.29	0.27	0.16	-	-	-
Petrol	1.21	1.55	1.43	1.57	1.10	0.31
Microbus	**0.79**	**0.89**	**0.83**	**0.88**	**0.97**	**1.09**
Diesel	0.78	0.85	0.68	0.64	0.63	0.63
LPG	0.01	0.00	0.00	-	-	-
Electricity	0.01	0.03	0.15	0.24	0.34	0.46
Bus minibus	**7.13**	**7.69**	**7.50**	**8.23**	**9.46**	**10.95**
Electricity	0.00	0.46	1.92	3.07	4.31	5.71
Diesel	7.12	7.23	5.58	5.17	5.15	5.24
E rickshaw	**0.02**	**0.03**	**0.03**	**0.04**	**0.05**	**0.07**
Electricity	0.02	0.03	0.03	0.04	0.05	0.07
Frieght	**30.76**	**34.46**	**42.81**	**53.21**	**67.06**	**84.04**
Truck/minitruck	**10.50**	**11.76**	**14.61**	**18.19**	**22.96**	**28.81**

Branch	2022	2025	2030	2035	2040	2045
Diesel	10.50	11.76	14.61	18.10	22.72	28.37
Electricity	-	-	-	0.09	0.23	0.44
Tractor	**12.80**	**14.34**	**17.81**	**22.14**	**27.89**	**34.94**
Diesel	12.80	14.34	17.81	22.06	27.70	34.58
Electricity	-	-	-	0.07	0.19	0.36
Pickup	**7.46**	**8.36**	**10.39**	**12.89**	**16.21**	**20.28**
Diesel	7.46	8.36	10.39	12.86	16.15	20.17
Electricity	-	-	-	0.02	0.06	0.11
Total	**64.92**	**69.23**	**68.35**	**76.42**	**89.58**	**106.94**

C. Net Zero Emission Scenario (PJ)

Branch	2022	2025	2030	2035	2040	2045
Passenger	**34.15**	**35.97**	**35.91**	**33.68**	**28.47**	**18.51**
Car/Jeep/Van	**4.98**	**5.48**	**6.02**	**6.49**	**6.87**	**6.96**
Electricity	0.03	0.42	1.31	2.61	4.46	6.96
Petrol	4.35	4.45	4.14	3.42	2.12	-
Diesel	0.60	0.61	0.57	0.47	0.29	-
Motorcycle	**19.72**	**20.33**	**19.28**	**16.52**	**11.39**	**2.79**
Electricity	0.00	0.16	0.52	1.04	1.78	2.79
Petrol	19.72	20.17	18.76	15.48	9.61	-
Tempo	**1.51**	**1.56**	**1.48**	**1.29**	**0.91**	**0.28**
Electricity	0.01	0.02	0.06	0.11	0.18	0.28
LPG	0.29	0.30	0.28	0.23	0.14	-
Petrol	1.21	1.24	1.15	0.95	0.59	-
Microbus	**0.79**	**0.85**	**0.87**	**0.86**	**0.79**	**0.63**
Diesel	0.78	0.80	0.74	0.61	0.38	-
LPG	0.01	0.01	0.01	0.00	0.00	-
Electricity	0.01	0.05	0.13	0.24	0.41	0.63
Bus minibus	**7.13**	**7.73**	**8.22**	**8.49**	**8.45**	**7.79**
Electricity	0.00	0.44	1.44	2.90	4.98	7.79

Branch	2022	2025	2030	2035	2040	2045
Diesel	7.12	7.29	6.78	5.59	3.47	-
E rickshaw	**0.02**	**0.03**	**0.03**	**0.04**	**0.05**	**0.07**
Electricity	0.02	0.03	0.03	0.04	0.05	0.07
Frieght	**30.76**	**34.46**	**34.36**	**32.64**	**28.10**	**18.43**
Truck/minitruck	**10.50**	**11.76**	**12.04**	**11.94**	**11.12**	**8.88**
Diesel	10.50	11.76	10.96	9.20	5.88	-
Electricity	-	-	1.09	2.74	5.25	8.88
Tractor	12.80	14.34	14.25	13.45	11.45	7.25
Diesel	12.80	14.34	13.36	11.22	7.16	-
Electricity	-	-	0.89	2.24	4.28	7.25
Pickup	**7.46**	**8.36**	**8.07**	**7.25**	**5.53**	**2.29**
Diesel	7.46	8.36	7.79	6.54	4.18	-
Electricity	-	-	0.28	0.71	1.35	2.29
Total	**64.92**	**70.43**	**70.27**	**66.33**	**56.57**	**36.94**

Annex 3: Characteristics of vehicles segregated by fuel types

Vehicle type	Petrol	Diesel	LPG	Electricity
Specific energy (MJ/ Pkm)				
Car/jeep/van	0.63	1.14		0.34
Motorcycle	0.76			0.39
Bus/minibus		0.27		0.11
Microbus		0.55	0.28	0.15
Tempo	0.60		0.31	0.03
E rickshaw				0.12
Specific energy (MJ/ tkm)				
Truck/minitruck		1.65		
Pickup		4.54		
Tractor		6.72		

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