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Energy Demand Modelling and Emission Forecasting: A case study of Sudurpaschim Province

Suraksha Pal [a], Nawraj Bhattarai [b], Ajay Kumar Jha [c], Hari Darlami [d]

[a, b, c, d] *Department of Mechanical and Aerospace Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[a] surakshapal30@gmail.com

Abstract

This research paper focuses on the development of future energy demand and emissions projections for the road transport sector in Sudurpaschim Province of Nepal, spanning from 2022 to 2050. This analysis utilizes the Long-range Energy Alternative Planning (LEAP) modeling framework and explores three distinct policy strategies: Business As Usual (BAU), Nationally Determined (NDC) Scenario and Long Term Strategy (LTS) Scenario. In 2022, passenger travel demand stood at 3.89 billion passenger kilometers, but it is anticipated to surge to more than 11.77 billion passenger-kilometers by 2050. Similarly, freight transport demand is expected to grow from 1.84 billion ton-kilometers in 2022 to 3.25 billion ton-kilometers by 2050. To meet these escalating transportation demands, the total final energy consumption (TFES) must increase from 2.59 PJ to 7.34 PJ, primarily relying on imported fossil fuels, with an annual growth rate of 3.78% from 2022 to 2050 under a business-as-usual scenario. During this period, greenhouse gas (GHG) emissions are projected to rise from 111.7 thousand MT of CO2 equivalent to in 2022 to 258.8 thousand MT of CO2 equivalent by 2050, representing a 3.41% annual growth rate. However, under the Nationally Determined Contribution (NDC) scenario, the total final energy consumption (TFES) must increase from 2.59 PJ to 3.7 PJ, primarily relying on electricity as a major fuel, with an annual growth rate of 1.32% from 2022 to 2050. During this period, greenhouse gas (GHG) emissions are projected to decline from 111.7 thousand MT of CO2 in 2022 to 30.8 thousand MT of CO2 equivalent by 2050, representing a CAGR of 4.49%. In Long Term Strategy (LTS) scenario, the energy demand is projected to rise from 2.6 PJ in 2022 to 3.0 PJ in 2050 with a CAGR of 0.48% while in case of pollutants, net zero emission is forecasted at targeted by the policy itself. When assessing the contrast between BAU with NDC and LTS scenarios, in 2025, energy demand reduced by 3.16%, 21.09%, 28.61%, 36.79%, 43.31%, and 49.00% in 2025, 2030, 2035, 2040, 2045, and 2050, respectively in case of NDC with respect to BAU. Similarly, the LTS scenario as compared to BAU indicated reductions of reductions of 6.99%, 19.11%, 31.78%, 44.95%, 58.56%, and 59.61% in 2025, 2030, 2035, 2040, and 2045, and 2050 respectively. When assessing the contrast between BAU with NDC and LTS scenarios, in 2025, emissions reduced by 4.9%, 32.8%, 49.3%, 65.81%, 77.9%, and 89.2% in 2025, 2030, 2035, 2040, 2045, and 2050 in case of NDC with respect larger reductions to BAU scenario. Similarly, the LTS scenario as compared to BAU indicated reductions of 13.0%, 34.8%, 56.5%, 78.3%, and 100% in 2025, 2030, 2035, 2040, and 2045, respectively.

Keywords

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

1. Introduction

The growth in population, coupled with rising per capita income, ongoing economic development, and the swift tide of urbanization, has ushered in an era of unprecedented motorization and fuel consumption. Undoubtedly, these advancements have enhanced certain aspects of human life; however, they also cast a formidable shadow of hazards upon society. This juxtaposition has made urbanization, especially in regions of emerging development like the Sudurpaschim province of Nepal, a matter of critical significance. It necessitates meticulous planning and organization to ensure that the trajectory of development is both sustainable and well-structured.

Central to this challenge is the imperative to establish a transportation system that not only meets the needs of the populace but also encourages the use of sustainable and energy efficient public modes of transport. From the perspective of transportation service users, four indispensable factors underpin public satisfaction: time, cost, dependability, and comfort. Addressing the public's demand for reliable public transport hinges on a few key urban transport prerequisites in the Sudurpaschim province. These requirements include the effective management of travel demand across various modes of transport, equitable allocation of road space favoring pedestrians and public transit, and the enhancement of public transport networks and facilities to improve operational efficiency and traffic management. Hence, it is of utmost importance that energy demand modeling and emission forecasting for this specific province be conducted, considering the unique challenges and opportunities it presents. These efforts will guide the development of a sustainable transportation system that aligns with the province's growth aspirations while mitigating the adverse effects on the environment.

However, these ambitions must be achieved within the framework of a low-carbon development path. It is crucial to prioritize the promotion of low-carbon vehicles and sustainable transport practices to ensure the long-term sustainability of the region's transportation systems. The concept of a low-carbon city emerges as a strategic and effective approach to reducing carbon emissions without compromising urban economic growth. Every sector within a city, especially transportation, and industry, plays a pivotal role in curbing emissions. In Nepal, the transportation sector stands out as a significant emitter of greenhouse gases (GHGs) and local pollutants, including CO_2, CO, SO_x, N_2O, and particulate matter. Moreover, it is a major consumer of energy derived from fossil fuels. While transportation is vital for economic prosperity and personal mobility, it cannot be denied that it also remains a substantial source of GHGs, making it imperative to address these challenges in pursuit of a sustainable and low-carbon future.

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

The goal of the study was to shed light on potential avenues for energy consumption and environmental effects, providing useful data for developing sustainable energy plans and policies. The major objectives of this study are mentioned below:

- Assess the current energy demand and emissions in the transportation sector
- Develop a transport-specific energy model for projecting energy demand up to 2050
- Estimate greenhouse gas emissions, forecasting them up to 2050 in various scenarios at 5-year intervals

1.1 Study Area

The research aimed to conduct a comprehensive study on energy demand modeling and emission forecasting in the transportation sector of Sudurpaschim Province, Nepal. The region was selected as the study site due to its unique socio-economic, geographical, and transportation characteristics, which made it an ideal representative for examining energy consumption patterns and environmental impacts within the context of Nepal's sustainable development goals. Figure 1.

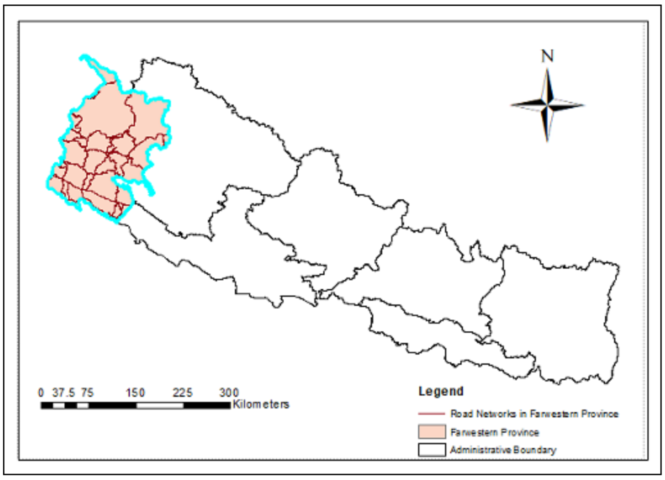

Figure 1: The study area Sudurpaschim Province of Nepal

1.2 Literature and Policy overveiew

The use of hydroelectricity in the transportation sector reduces reliance on fossil fuels and greenhouse gas emissions, which helps to address the problem of energy security. The use of electric vehicle scenario can result in a cumulative reduction of about 46 thousand metric tonnes CO2e (21.9%) of GHG emissions between 2013 and 2050. The electric mass transportation scenario can result in a reduction of about 60 thousand metric tonnes (27.3%), and the combined scenario would see a reduction of about 80 thousand metric tonnes(37%) [1].

In order for Kathmandu Valley to meet the 30% cumulative CO2 emission reduction target (ER30), a significant shift in the region's energy consumption patterns from gas and oil to electricity would be required. Moreover, in the ER30 scenario, the proportion of electricity in the transportation sector's overall energy consumption could increase from 12% in the base case to 24% [2].

Compared to the baseline scenario, approximately 38% of energy demand and 54% of CO2 emissions can be avoided if alternative scenarios like improved fuel economy, public transport, electric motorcycles, and hybrid electric cars are implemented at the same time during the study period [3]

The cumulative Total Final Energy Consumption (TFES) and cumulative GHG emissions decreased by .97% and 1.19%, respectively, under the electric vehicle scenario from 2012 to 2050. In the case of electric mass transit, TFES drops by 1.27% and cumulative GHG emissions drop by 1.61% from 2012 to 2050. Furthermore, the combined scenario results in a 1.68% decrease in TFES while 2.26% GHG emissions [4].

According to a study, encouraging electric vehicles, public transportation, and faster driving could all cut energy consumption by 18%,28%, and 28%, respectively. Combining all of the aforementioned policies canreduce CO_2 emissions in 2020 by more than 60% compared to the non-intervention case [5].

A study suggested that in the reference scenario, energy consumption increased threefold from 544 PJ to 1645 PJ between 2017 and 2050. In 2017, 69 million metric tons of CO2 equivalents were emitted, averaging 2.36 metric tons per person. The reference scenario projected a rise in per capita carbon emissions to 4.06 metric tons in 2050, resulting in a total of 178 million metric tons of CO2 equivalent. Despite technological policy interventions in a sustainable scenario, per capita emissions decreased to 0.64 metric tons in 2030, but overall emissions increased to 21.95 million metric tons of CO2 equivalent[6].

The Government of Nepal has targeted promotion of electric vehicles through various policies, such as the Second Nationally Determined Contribution, Long-Term Strategy for

Net-Zero Emissions, 15th Periodic Plan, etc. Additionally, numerous researches have been conducted related to low carbon electric mobility in context of Nepal. Sustainable Development Goals implementation policy in Nepal has targeted to increase in share of electric vehicle in public transport from 1% in 2020 to 35% in 2025 and 50% in 2050.[7]

Nationally Determined Contribution: Nepal's Nationally Determined Contribution (NDC) targets: 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 CO2eq to 2,734 Gg CO2eq. [8]. 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 CO2eq to 2,619 Gg of CO2eq. [9]. By 2030, develop 200 km of electric rail network to use as public travelling as well as freight transportation.

Nepal's Long-term Strategy for Net-zero Emissions (LTS) has been prepared with the objective of developing Net-Zero emissions by 2050 in different economic sectors. It compares emission reduction in 2030 and 2050 with existing and added measures. According to LTS, 1.9 million Metric tonnes of CO2 equivalent emission reduction can be achieved in 2030 and 8.2 million Metric tonnes of CO2 equivalent reduction in 2050, i.e., 26% and 41% reduction in 2030 and 2050, respectively, compared to the reference scenario with existing measures and can be reduced to 97% by 2050 with additional measures.[9]

Transport is the second sector that receives the most government budget [10]. However, the people living in Nepal are deprived of affordable transport services. Over the few years, the number of vehicles in the country has increased. The number of private vehicles, mostly the motorcycles, has increased dramatically. This increment in several vehicles has effect on the import of petroleum products such as petrol and diesel. The significant increase in motor vehicles also caused frequent fuel shortages as the Nepal government cannot pay for fuel imports[11].

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

2. Methodology

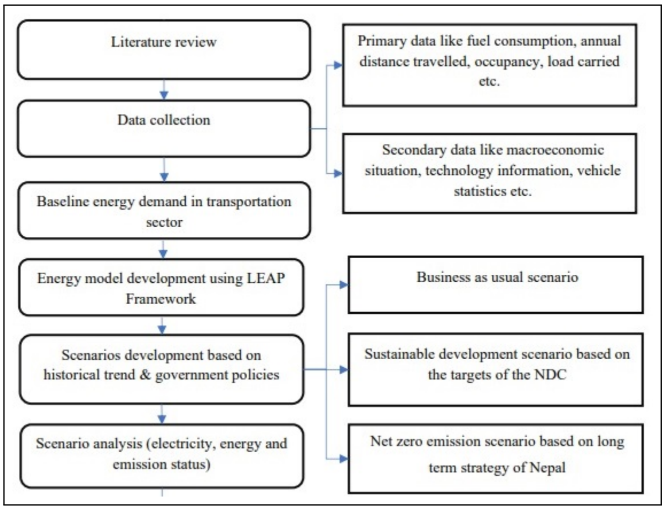

Figure 2: Flow chart showing overall research methodology

A combination of primary and secondary data from various sources was essential for modeling, calibration, and model validation. The methodology is shown above. Primary data was derived from surveys conducted on vehicles operating in Sudurpaschim Province. These surveys encompassed details such as vehicle type, mileage, and passenger occupancy rates, number of trips, fuel type, load-carrying capacity, and vehicle age, among others. On the other hand, secondary data was sourced from different outlets, including the Department of Transport Management along with various relevant literature pertaining to the study.

Low Emission Analysis Platform (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. The overall study design and reserch methodology is shown in Figure 3.

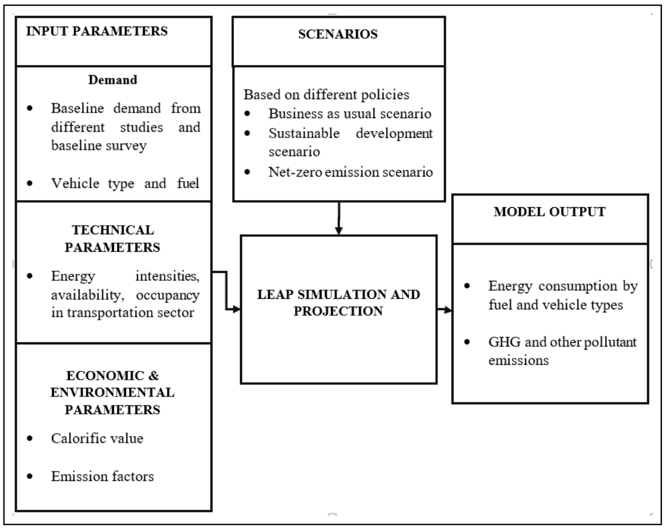

Figure 3: Flow chart showing overall research methodology

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

2.1 Sample Size Determination:

In order to provide a representative sample and produce accurate and generalizable results in survey research, the population size, desired confidence level, and margin of error were taken into account. The sample size was be determined by using Krejcie and Morgan Formula as shown in Equation 1.

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

Where, x^2 is the square value for a specific confidence level of 95%, p is the probability of success,q is the probability of failure, e is the margin of error, N is population size and n is the required sample size.

2.2 Calculation of major parameters:

a. Energy Consumption:

$$Ex = Q * cv * n \tag{2}$$

Where, E_x is the annual energy consumption of the vehicle, cv is Calorific value of the fuel, n is the number of operating days.

$$SEC = \frac{1}{n} * \Sigma(Ex) \tag{3}$$

Where, SEC is the specific energy consumption

$$TEC = \Sigma SEC * Nv \tag{4}$$

Where, Q is the quantity of fuel per month, cv is Calorific value of the fuel, n is the number of operating days, TEC is the total energy consumption and N_v is the total number of vehicles.

b. Energy Intensity: The amount of fuel consumed per unit degree of activity per passenger-kilometer. It is expressed in terms of Megajoule per passenger kilometer (MJ/pkm) for passenger vehicles and Megajoule per tonne kilometer for freight vehicle (MJ/tkm).

c. Travel Demand: The study takes road transport into account for the projection of energy demand in the transportation sector. The total travel demand in the LEAP model was expressed as tonne-kilometer(tkm)for freight and passenger-kilometer (pkm) for passenger transportation.

Travel demand of passenger vehicles (passenger-km): The total travel demand for passenger vehicle is calculated by using the formula below:

$$pkm = \Sigma V_i(n) * VKT_i(n) * AO \tag{5}$$

Where, pkm is the passenger kilometer, $V_i(n)$ is the no. of the vehicle of type i in year n, $VKT_i(n)$ is the annual average vehicle kilometer traveled by that type of vehicle in the same year, AO is the occupancy rate in vehicle in terms of number of people.

Travel demand freight vehicles (Tonne-km) The total travel demand for freight vehicles is calculated by using the formula below:

$$tkm = \Sigma V_i(n) * VKT_i(n) * W \tag{6}$$

Where, tkm is the tonne-kilometer, $V_i(n)$ is the no. of the vehicle of type i in year n, $VKT_i(n)$ is the annual average vehicle kilometer traveled by that type of vehicle in the same year, W is the vehicle weight rate in terms of tonne.

Travel Demand Forecast: Energy service demand is one of the essentials for forecasting the energy consumption as well as emissions. In the study, passenger-km (for passenger vehicles) and tonne-km (for freight vehicles) have been taken as energy service demands. The service demand was calculated using the formula given below:

$$Dn = Do * (\frac{GVAn}{GVA_o})^{\alpha}1 * (\frac{Pn}{Po})^{\alpha}2 \tag{7}$$

Where, D_n is the service demand of n^{th} year, D_o is the service demand of base year, GVA_n is the gross value added for n^{th} year and GVA_o is the gross value added for base year is the elasticity for GVA and is the elasticity for population.

d. Energy Projection: The passenger-kilometer and tonne-kilometer are the major factors that determine the energy demand. LEAP calculated the demand using the formula given below:

For Passenger vehicles,

$$E_{i,n} = \Sigma pkm_{i,n} * FE_{i,n} \tag{8}$$

Where, E is the Energy demand in n^{th} year for vehicle type i, pkm is the passenger-kilometer in n^{th} year for the vehicle type i, FE is the fuel economy of i vehicle type in n^{th} year.

For freight vehicles,

$$E_{i,n} = \Sigma tkm_{i,n} * FE_{i,n} \tag{9}$$

Where, E is the Energy demand in n^{th} year for vehicle type i, tkm is the tonne-kilometer in n^{th} year for the vehicle type i, FE is the fuel economy of i vehicle type in n^{th} year.

Emission Forecast: The energy requirement of any type of vehicle and its efficiency are the major factors that determine the emissions from those vehicles. In LEAP, the emission factor is estimated using the formula:

$$E_y(n) = \sum V_i(n) * VTK_{ik}(n) * EF_{ik}(n) * F_i(n) \tag{10}$$

where E_y(n) is the total emission by vehicle type y in year n, EF_{ik}(n) is emission factor of pollutant k, by vehicle type i in year n, F_x (n) is fuel efficiency of vehicle in kilometers per liter in year n.

2.3 Scenario Development:

Scenario development serves as the fundamental requirement for formulating an integrated energy policy, establishing plans, and defining implementation activities. It involves scenario-based planning, a technique that 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. 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.

In this study three scenarios namely, (i) Business as Usual, (ii) Sustainable Development Scenario and (iii) Net Zero Emission Scenario, have been developed.

Business as Usual (BAU): In business as usual scenario, it assumed that the growth will take place as the historical trends it has been following in the past years.

Sustainable Development Scenario (SDG) The sustainable development scenario has been developed based on the targets of the Nationally Determined Contribution (NDC) of Nepal. The major consideration in this scenario are:

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

Net Zero Emission Scenario (NZE): The net-zero emission scenario has been developed based on the targets of the Long-term Strategy for net-zero emission. The major considerations within this scenario are:

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

2.4 LEAP Modelling:

For the study, a bottom-up energy system model built on the Low Emission Analysis Platform (LEAP) model framework has been created. There are two categories of energy demand: passenger demand and freight demand. Passenger transportation can be further classified according to the type of vehicle used, such as bus, car, rickshaw, motorcycle, etc. The vehicles used here for the analysis of freight transport are trucks, tractors, and power tillers.

3. Results and Discussion

3.1 Baseline case

a. Travel Demand: Approximately,4.9 billion passenger kilometers and 0.8 billion tonne-kilometers, respectively, make up the base year's travel demand. The percentage of travel demand for various vehicles is shown below in Figure 4. The share of freight service demand among various vehicle types is shown in Figure 5.

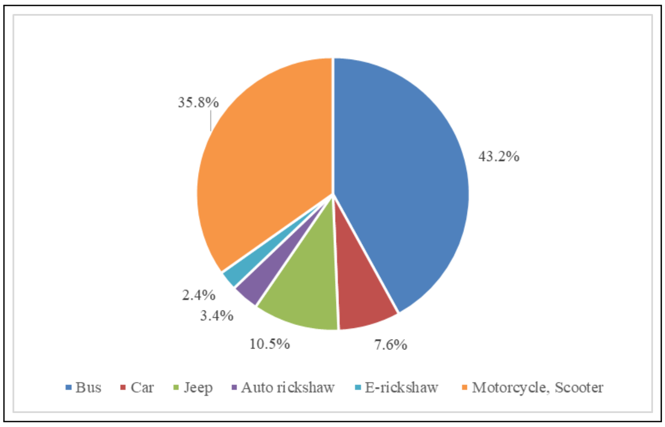

Figure 4: Travel demand for passenger vehicles in base year

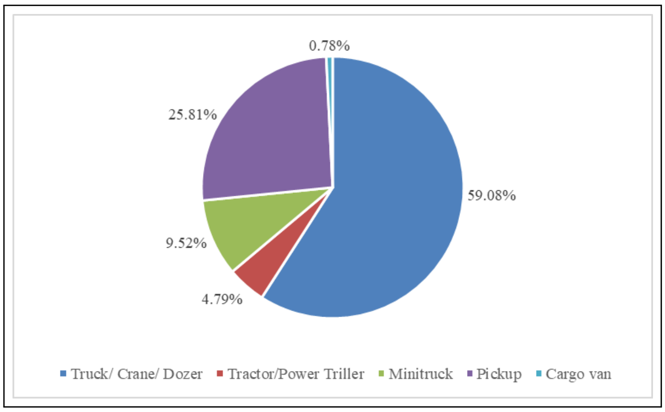

Figure 5: Travel demand for freight vehicles in base year

3.2 Future Travel Demand

By the use of historical data and projected parameters like Gross Domestic Product (GDP) and population, the regression model is used to forecast the travel demand for the province of

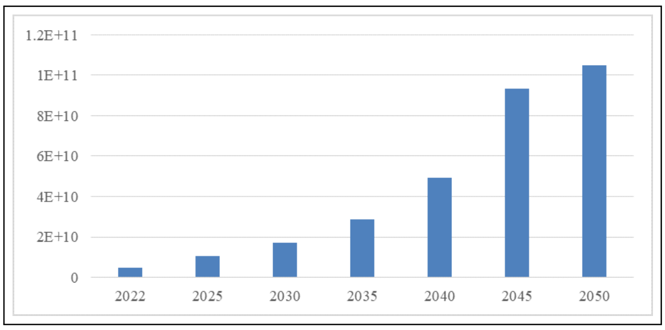

Figure 6: Travel demand for passenegr vehicles

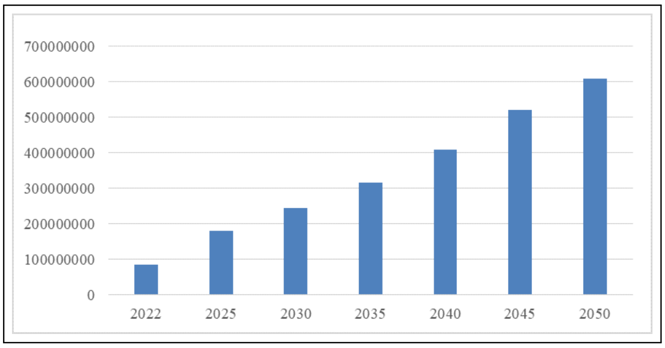

Figure 7: Travel demand for freight vehicles

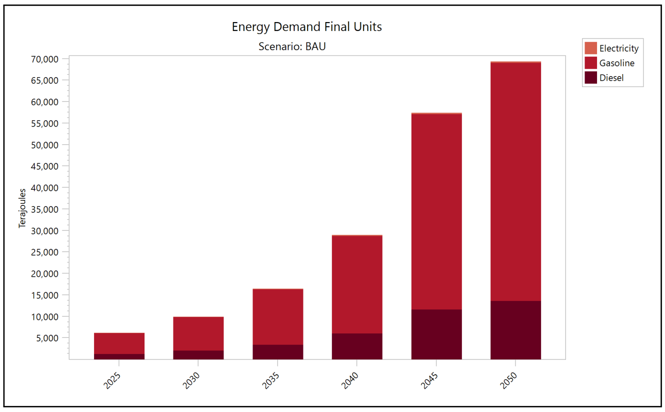

Figure 9: Energy consumption by fuel type for BAU scenario

Sudurpaschim. By 2050, the province's freight demand is predicted to reach over 21 tonne-km, while the demand for passenger travel is projected to reach over 240 billion passenger-km. The projected travel demands in case of passenger vehicle and freight vehicle is shown in Figure 6 and **Figure 7** respectively.

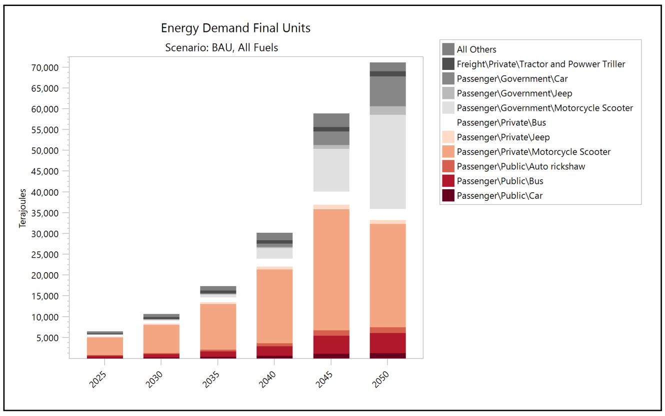

Figure 10: Energy consumption by vehicle type for BAU scenario

3.3 Energy Demand

3.3.1 Business as Usual Scenario (BAU)

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 consumption for different years for different sectors like private, public, government and institution is shown in **Figure 8**.

The total energy consumption for different years for different fuel types is shown in **Figure 9**.

The total energy consumptions for different years for different vehicle types is shown in **Figure 10**.

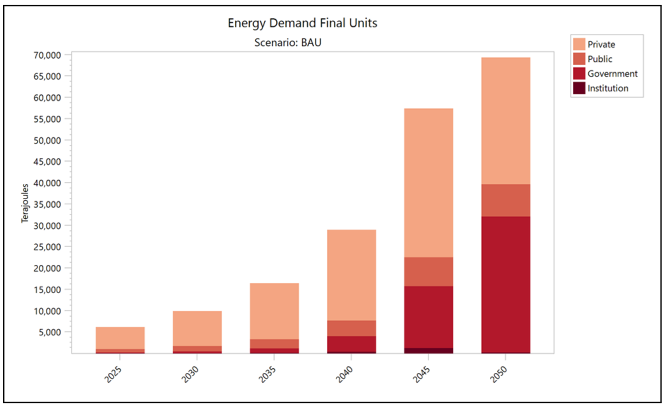

Figure 8: Sectoral Energy Consumption for BAU scenario

3.3.2 Sustainable Development Scenario

The sustainable development (SD) scenario has been developed based on the historical trend of fuels used in different vehicles in Nepal along with the targets based on the commitments of the second Nationally Determined Contribution (NDC) of Nepal.

The total energy consumptions for different years for different sectors of transportation like public, private, government and institution is shown in **Figure 11**.

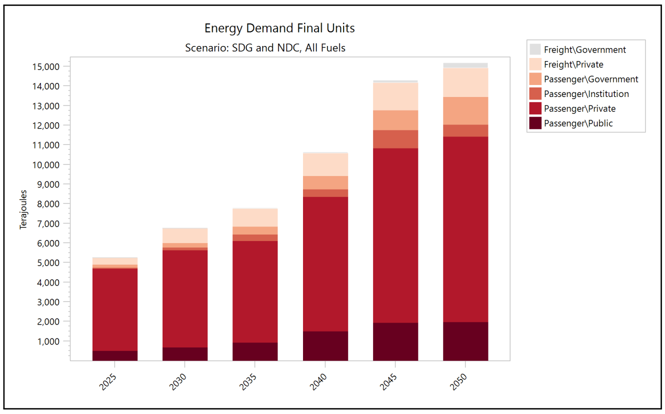

Figure 11: Sectoral Energy Consumption for SDG scenario

The total energy consumptions for different yearsand for different fuel type is shown in **Figure 12**.

The total energy consumption for different years for different vehicle types is shown in **Figure** 13.

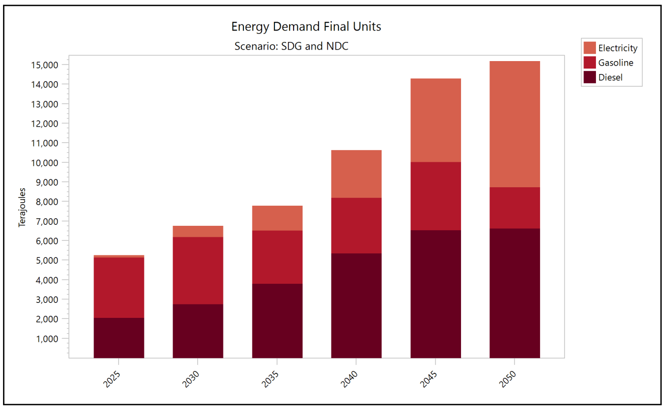

Figure 12: Energy consumption by fuel type for SDG scenario

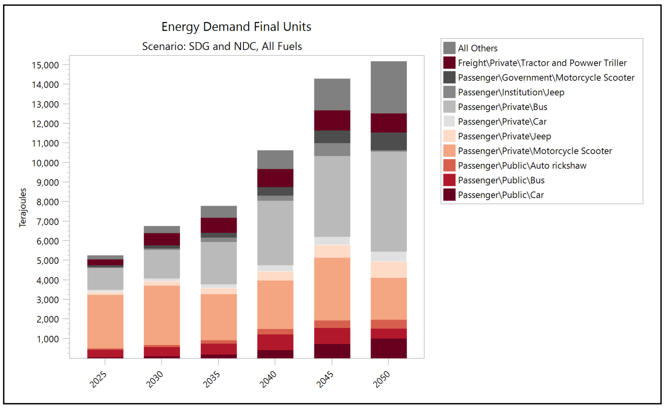

Figure 13: Energy consumption by vehicle type for SDG scenario

3.3.3 Net Zero Emission Scenario

The net-zero emission scenario has been developed based on the targets of the Long Term Strategy (LTS) for net-zero emission. The total energy consumption for different years for different sectors of transportation is shown in Figure 14.

The total energy consumption pattern for different years for different fuel types is shown in Figure 15.

The total energy consumption pattern for different years for different vehicle type is shown in Figure 16.

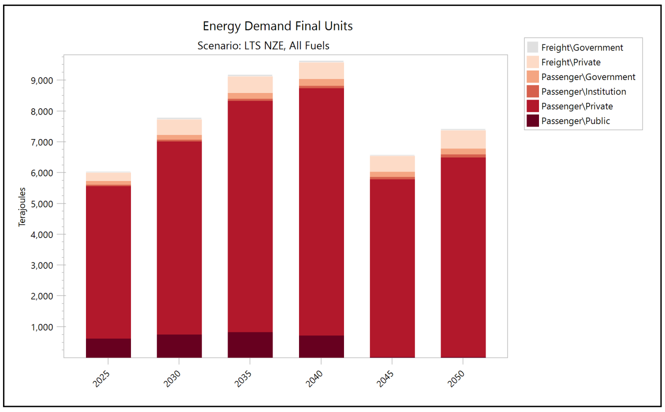

Figure 14: Sectoral Energy Consumption for NZE scenario

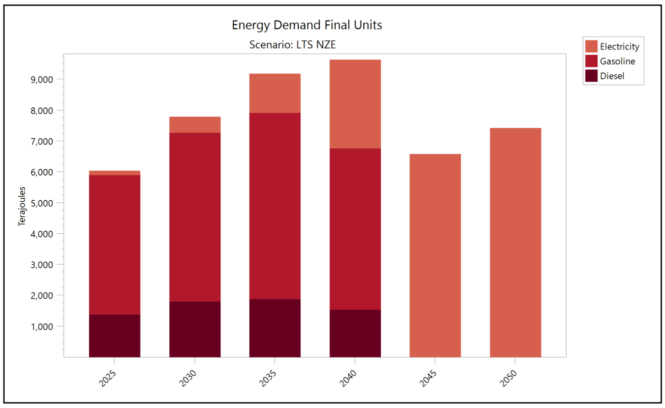

Figure 15: Energy consumption by fuel type for NZE scenario

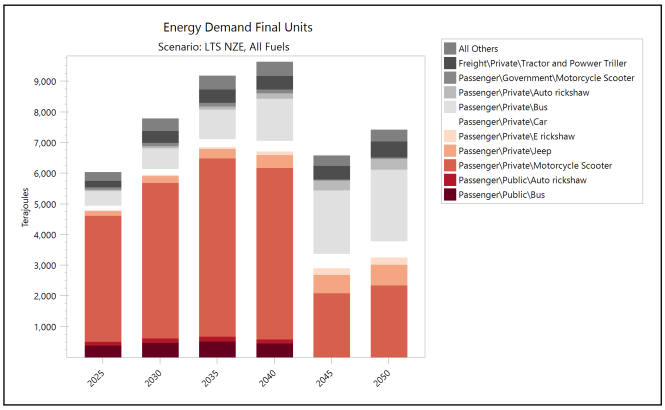

Figure 16: Energy consumption by vehicle type for NZE scenario

3.4 Emission Forecast

The GHG emission in the base year for the transportation sector is estimated to be 8,600 thousand MTCO2eq at 100-year global warming potential (GWP). The details of GHG emissions for all three scenarios over the yaers upto 2050 is shown in **Table1**

3.5 Comparative analysis

The altitude map of study is shown in Figure 17.

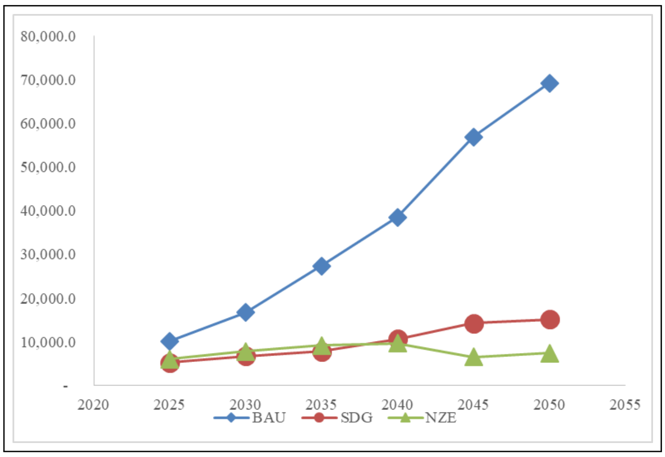

Figure 17: Energy demand in all scenario

BAU							
GHGs	2025	2030	2035	2040	2045	2050	Total
CO_2	10,132.9	16,662.8	27,271.1	47,361.2	92,568.2	111,830.3	305,827.3
CH_4	12.8	21.0	34.4	59.8	117.1	141.6	690.7
N_2O	22.9	37.5	61.5	106.9	209.1	252.1	690.5
Total	10,168.7	16,721.4	27,367.7	47,528.9	92,894.8	1112,224.6	306,904.5
SDG							
GHGs	2025	2030	2035	2040	2045	2050	Total
CO_2	8,296.8	9,975.8	10,646.1	13,424.2	16,307.7	14,042.6	72,666.4
CH_4	10.4	12.4	13.0	16.1	19.1	15.6	86.7
N_2O	18.5	22.2	23.5	29.5	35.9	30.8	160.5
Total	8298.7	10,010.4	10,682.6	13,469.9	16362.8	14,089.1	72,913.5
NZE							
GHGs	2025	2030	2035	2040	2045	2050	Total
CO_2	9,298.4	11,457.8	12,467.6	10,668.5	-	-	43,892.4
CH_4	11.8	14.5	15.8	13.5	-	-	55.6
N_2O	21.0	25.9	28.2	24.1	-	-	99.1
Total	933.2	11498.1	12511.6	10706.2	-	-	44047.1

Table 1: GHG emission in all three scenarios

The altitude map of study is shown in Figure 18.

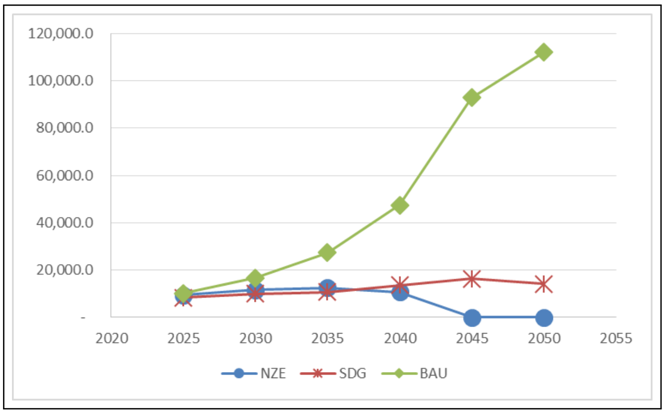

Figure 18: Emission in all scenario

4. Conclusions

This study used a LEAP modeling framework to analyze the various effects of policies regarding the transportation sector in Sudurpaschim province of Nepal under three distinct scenarios from 2022 to 2050 to explore the perspective of electric vehicle penetration. The baseline annual consumption (BAU) scenario, which assumed that current trends would persist, has revealed a sharp rise in energy demand and associated emissions. This research paper focuses on the development of future energy demand and emissions projections for the road transport sector in Sudurpaschim Province of Nepal, spanning from 2022 to 2050. This analysis utilizes the Long-range Energy Alternative Planning (LEAP) modeling framework and explores three distinct policy strategies: Business As Usual (BAU), Sustainable Energy Development (SDG) Scenario and Net Zero Emission Scenario. In 2022, passenger travel demand stood at 4.01 billion passenger-kilometers, but it is anticipated to surge to more than 105 billion passenger-kilometers by 2050. Similarly, freight transport demand is expected to grow from 84 million ton-kilometers in 2022 to 610 million ton-kilometers by 2050. To meet these escalating transportation demands, the total final energy consumption (TFES) must increase from 1,249.1 TJ to 71,082.7 TJ, primarily relying on imported fossil fuels, with an annual growth rate of 10.58% from 2022 to 2050 under a business-as-usual scenario. During this period, greenhouse gas (GHG) emissions are projected to rise from 1.02 mMT of CO2 equivalent to in 2025 to 11.2 mMT of CO2 equivalent by 2050, representing a 10.08% annual growth rate. However, under the sustainable development scenario, the cumulative TFES 1,249.1 TJ in 2022 to 15,165.2 TJ in 2050.

The alternative scenarios have demonstrated how steps like promoting the use of electric vehicles and switching from gasoline and diesel to electricity-powered vehicles can help limit the rise in energy consumption and pollution levels. The study emphasizes the benefits of fuel shift in the transportation sector to lessen reliance on fossil fuels and greenhouse gas emissions, which addresses the problem of energy security.

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