PROJECTING ENERGY DEMAND AND GHG REDUCTION WITH ELECTRIC VEHICLE ADOPTION IN NEPAL

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Abstract:
Nepal has been rapidly adopting electric vehicles (EVs) to achieve its long-term strategy for net-zero emissions; however, the transportation sector still heavily relies on imported fossil fuels. This study uses a sample survey to develop the baseline of energy consumption in the transportation sector and accordingly forecasts energy and emissions in the transportation sector using a macroeconomic model. In this study, the Low Emission Analysis Platform (LEAP) modelling tool is used to forecast energy demand and greenhouse gas emissions (GHGs) in the transportation sector of Nepal. Based on historical energy use trends in the sector and the Government of Nepal's policies, three scenarios were developed: Business as Usual (BAU), Sustainable Development (SD), and Net-Zero Emission (NZE). In the base year, i.e. 2022, the energy consumption in the transportation sector amounts to 64.92 PJ. The BAU scenario, based on the historical energy consumption pattern, projects an increase in overall energy demand to 92.41 PJ by 2030 and 180.46 PJ by 2045, with a compound annual growth rate (CAGR) of 4.55%. The electricity consumption in the transportation fuel is expected to rise from 0.07 PJ in 2022 to 0.64 PJ by 2045, while GHGs are projected to increase to 11.39 $mMTCO_{2eq}$ by 2045. Similarly, in the SD scenario, based on the targets of the second nationally determined contribution (NDC), energy demand is projected to reach 68.35 PJ by 2030 and 106.94 PJ by 2045, with electricity penetration increasing at a CAGR of 26.68% and GHGs amounting to 6.55 $mMTCO_{2eq}$ by 2045. The NZE scenario anticipates energy demand peaking at 70.27 PJ by 2030 before declining to 36.94 PJ by 2045, with electricity demand growing at a CAGR of 31.12%. GHGs are projected to reach 4.41 $mMTCO_{2eq}$ by 2030 and achieve NZE by 2045.

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1. INTRODUCTION

Growing global concerns regarding climate change, energy security and escalating oil prices have increased the focus on developing sustainable and energy-efficient transportation systems [1]. EVs are increasingly considered as an alternative viable option to the traditional internal combustion engine (ICE) vehicles that cater to the sustainable development and foster low-carbon, resilient development [2-4]. Nepal's transportation sector has seen rapid growth, with registered vehicles increasing from 2 million in 2014 to 5.5 million by mid-march 2024, with a CAGR of 12% [5]. However, the sector still exhibits high dependency on fossil

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fuels, and is dominated by diesel and petrol ICE vehicles.

Although Nepal contributes only 0.027% to global carbon dioxide emissions, it has prioritized net-zero emissions through its various National Plans and Policies. Analysis of Nepal's national GHG inventory reveals that the energy sector accounts for 28.60% out of which the transportation sector contributes 29.97% of the GHG emission [6]. Nepal, as a signatory to the Paris Agreement, has targeted to achieve net zero emissions by 2045 while reducing emissions in the transportation sector by 97% [6]. The national energy policies of Nepal outline progressive targets for electricity consumption, projecting an increase from 400 kWh to 700 kWh per capita by 2085/86 [7], with further aspirations of achieving 1,500 kWh per capita and 28,500 MW installed capacity by 2035 to support the electric mobility transition [8]. The additional electricity needed for Kathmandu valley by 2050 is estimated at approximately 1048 GWh under the SD scenario and 1390 GWh under the NZE scenario [9].

The total energy consumption of Nepal in the year 2022 was 640 PJ and has been increasing at a CAGR of 3.44% since 2009 [10]. In 2022, the overall energy consumption in the transportation sector in Nepal was 67.10 PJ [11]. Out of which, 60.34% is due to diesel consumption, followed by petrol consumption at 31.60% and aviation turbine fuel consumption at 8.04% [12]. The scenario-based approach using the model for analysis of energy demand (MAED) was employed to analyse the increase in energy demand across diverse economic sectors. 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% from 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 gross domestic product by 3.1% compared to the base case [13]. The total vehicular emissions in the Kathmandu 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% [14]. 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% [14]. The penetration of plug-in hybrid EVs (75% of the total cars) can decrease the energy consumption by 1%, CO_2 emissions by 2%, and PM_{10} by 10% [15]. 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% [15]. The [16] reported that the major pollutants from the 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 and concluded that adhering to the Euro III standard for all vehicles would decrease emissions of toxic air pollutant (excluding CO_2) by 44% and climate-forcers by 31% in as compared to the base case in 20 year horizon. The effect of emission reduction targets on the energy mix in the Kathmandu Valley projects that the transportation sector's energy consumption would increase to 11.41 PJ by 2020 and 20 PJ by 205 [17]. Modelling outcomes show energy demand reductions of 28% from both increased vehicle speeds and enhanced public transportation utilization, and 18% from EV adoption [18]. Nepal's goal is to achieve net zero emissions from 2020-2030, and after a period of very low emissions, to full net zero by 2045. [19]. 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 [20]. 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 [20].

A grey forecasting model, as used by [21], was employed to forecast the number of motor vehicles, energy demand by vehicles, and CO_2 emissions in Taiwan. Another study by [22] used Grey Prediction with a rolling mechanism approach to predict Turkey’s total and industrial electricity consumption. To forecast the long-term energy demand of the Croatian transportation sector [23], a bottom-up model was used. Integrated MAED-MARKAL-based analysis is used by [24] to develop energy systems in Nepal, while Econometric models are used for forecasting energy demand in Nepal [25]. The LEAP-IBC modelling framework derived the current status of short-lived climate pollutants emissions in Nepal [26]. The LEAP modelling tool, used by [27] to estimate energy consumption and emissions of the transport sector in Malaysia, found that the total road sector energy consumption from 2012 to 2040 will increase by approximately 3.7 times.

The rapid growth of vehicle imports in Nepal has intensified energy demand in the transportation sector, leading to higher fuel imports and subsequent growth in GHG emissions. The EV market in Nepal shows promising hidden demand, yet the lack of effective government policies, charging infrastructure, and available vehicles remains a major bottleneck for adoption [28]. The growing adoption of EVs will substantially increase national energy demand, require stable grid connections specialized distribution infrastructure [29]. Although EV adoption presents a sustainable alternative, it also strains the electricity supply and requires extensive charging infrastructure development. The majority of remote areas lack access to roads and energy; the current distribution of EV across the country is not uniform and concentrated in cities [30]. In Nepal, the main obstacles to EV adoption include limited charging infrastructure, higher purchase prices relative to ICE vehicles, and insufficient government planning and target-setting for long-term EV integration [31]. A decrease in purchase price has the strongest impact on boosting consumer adoption of battery EVs and plug-in hybrid electric vehicles [32]. This dual challenge, managing rising fossil fuel dependence alongside expanding EV integration, underscores a critical gap in Nepal's transport energy planning. Addressing these interconnected issues is vital for transitioning to an efficient and low-carbon mobility system.

The research aims to develop baseline energy consumption within Nepal's transportation sector and to forecast the energy demand in alignment with Nepal's plans and policies. The study further aims to project the growth of EVs and the corresponding GHG mitigation necessary to achieve the targets outlined by the second NDC and long-term strategy for net zero emissions. Moreover, the study also analyses the powerplant capacity required to meet the increasing electricity demand resulting from EVs penetration.

2. MATERIALS AND METHODS

2.1 Sample Size Determination

The total number of vehicles registered in Nepal by 2022/23 was 5.2 million, most of which were motorcycles [33]. However, not all of these vehicles were in operation. Considering the operating factor as analyzed by [20], the number of vehicles in operation in Nepal was calculated and presented in Table 1.

Table 1. Vehicle in operation in Nepal (2022/23)

S.N.	Vehicle	Number of registered vehicles	Operating factor	Vehicles in operation
1.	Motorcycle	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

Sampling is the method used to identify the number of samples and the sample units from a population using statistical methods such that it possesses the characteristics of the population. Sampling was conducted to determine the appropriate sample size and units in the transportation sector. The number of vehicles in operation was considered as the population, and individual vehicles were considered as the sample unit. For proportional determination of sample size, it was designed with a 95% level of confidence with 5% marginal error and 5% non-response rate for the transportation sector. The sample size was calculated using the (Krejci and Morgan formula) as indicated in Eq. (1.

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

where are:

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.

The actual sample required – *As* can be calculated using Eq. 2:

$$A_s = n + 5\% \times n_r \tag{2}$$

where is:

n_r - Total non-response rate = 5%.

The overall sample size was thus calculated to be 404. The calculated sample size has been further categorized into different types of vehicles. For better consistency, at least 3 vehicles in each category and an extra 5% number have been considered for the survey. The detailed sample size of different vehicles for data collection is shown in Table 2.

Table 2. Sample based on the type of vehicles

S.N.	Vehicle	Actual sample taken
1.	Motor cycle	355
2.	Tempo	8
3.	Car/jeep/van	21
4.	Micro bus	3
5.	Bus/Minibus	6
6.	Truck/Mini truck	9
7.	Pick up	10
8.	Tractor	15
9.	E rickshaw	3
	Total =	430

2.2 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. 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.

The annual energy consumption of the individual vehicle -$A_{ec}(E_x)$ has been calculated using Eq. 3. This calculation scales a known monthly fuel consumption to an annual energy value. The method first computes a daily fuel rate, then annualizes it based on operational days. The final energy consumption is obtained by applying the fuel's calorific value to this total annual fuel amount.

$$A_{ec}(E_x) = Q_{fa} \cdot C_v \tag{3}$$

where are:

$A_{ec}(E_x)$ - Annual energy consumption of an individual vehicle,

Q_{fa} - Quantity of fuel per annum,

C_v - Calorific value.

x – Category of vehicle.

The specific energy consumption of a vehicle, Sec, is obtained by adding the annual energy consumption of different sample vehicles to the total number of samples. The specific energy consumption of vehicles (Sec) and total energy consumption of vehicles (Tec) have been calculated using Eqs. 4 and 5 [34].

$$S_{ec} = \frac{1}{n}\sum(E_x) \tag{4}$$

$$T_{ec} = \sum S_{ec} \cdot Nv \tag{5}$$

where are:

S_{ec} – Specific energy consumption within vehicle category,

Nv -Total number of vehicles within the vehicle category

2.3 Development of Energy Model and Scenarios

2.3.1 Scenario Development

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 (GVA), 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 the same GVA, with different levels of penetration of EVs based on the government targets and policies, were developed

2.3.2 Service Demand Projection

The study utilizes the service demand projection methodology to forecast energy consumption in the transportation sector. For passenger vehicles, the service demand is measured in passenger-kilometres (pkm) and is influenced by both growth in population and the GVA of the sector. While for freight vehicles, service demand is measured in tonne-kilometres (tonne-km) and is driven solely by the GVA of the sector. The service demand has been calculated using Eq. 6 [20].

$$\begin{aligned} &Service\ demand\ of\ n^{th} year \\ &= Service\ demand\ of\ base\ year \\ &\times \left(\frac{GVA\ of\ n^{th} year}{GVA\ of\ base\ year}\right)\alpha_1 \\ &\times \left(\frac{GVA\ of\ n^{th} year}{GVA\ of\ base\ year}\right)\alpha_2 \end{aligned} \tag{6}$$

where are:

α_1 - is the elasticity for GVA,

α_2 - is the elasticity for the population.

The population and the GVA growth rate for the energy demand projection 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 a similar pattern of projected growth rates as published by the United Nations Department of Economic and Social Affairs. Similarly, the growth in GVA has been considered based on several national studies of Nepal, such as the Long-term strategy for NZE, Sustainable Development Goals, 16th Periodic Plan, Energy Sector Vision 2050, etc. [35]. The details of the growth rate in different scenarios are shown in Table 3.

Table 3. 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%
GVA	6.7%	7.5%	8%	8.5%	8.3%

It should be noted that, in this study, the growth rates of population and GVA are assumed to be constant across the projected periods.

2.3.3 Energy Model Development

In this study, the LEAP model, developed by the Stockholm Environment Institute (SEI), was utilised for forecasting energy demand and emissions. Specifically, the analysis was conducted using the LEAP 2022.1.804 version, which is a scenario-based integrated energy environment modelling tool. This version supports comprehensive assessment through its core modules, Key Assumptions, Demand, Transformation, and Resources, along with the Technology and Environment Database, enabling robust evaluation of energy consumption patterns, supply dynamics, and associated emissions under alternative development pathways. The LEAP provides an integrated platform for developing and analysing 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 model is currently utilized in over 190 countries by a wide range of stakeholders, including government bodies, consulting firms, academic institutions, energy service providers, and non-governmental organizations [36]. LEAP supports scenario-based energy modelling across all economic sectors as well as within the economic sector and provides the output in terms of the energy demand as well as GHG emissions and transformational change [37, 38]. The framework is highly flexible and customizable, allowing users to create models specific to a country's demographic and energy use patterns. LEAP can assist in the development of long-term scenarios, which can then be utilized 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 LEAP modelling framework is illustrated in Fig. 1

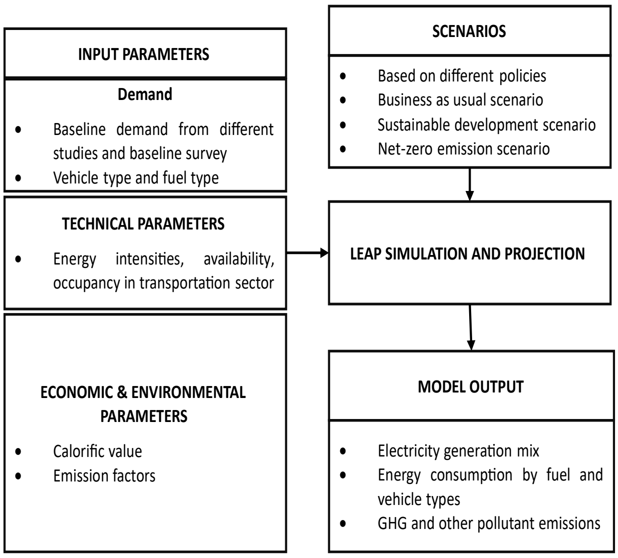

Fig. 1. Leap modelling framework

3. RESULTS AND DISCUSSION

3.1 Status of the Transport Sector in the Base Year

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, Liquefied Petroleum Gas (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 Fig. 2.

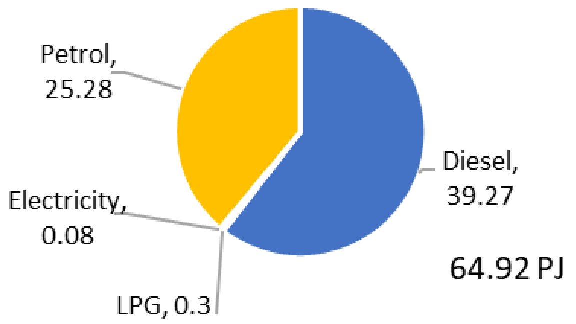

Fig. 2. Energy consumption by fuel type

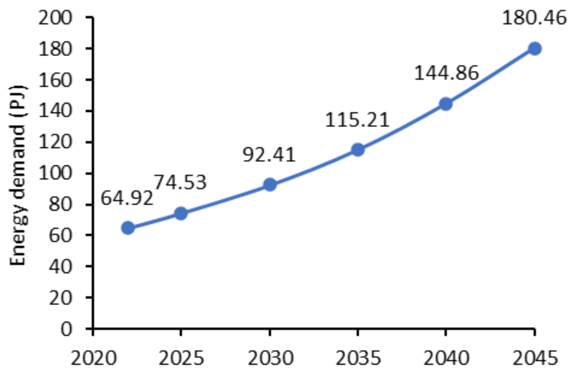

Fig. 3. Energy demand by the BAU scenario

3.2 Energy and Emission Projection

Conventional vehicles are responsible for significant fuel consumption and emissions. However, advancements in conventional vehicle technologies present opportunities for improving efficiency, thereby reducing energy use and associated emissions. It should also be noted that fuel consumption and exhaust gas emissions can be further reduced through complementary measures, such as improving transmission efficiency, minimizing frictional losses. This study considers 2022 as the base year for energy demand analysis, with projections extending to 2045. For the base year, the energy model was developed using collected and analyzed data.

3.2.1 Business as Usual Scenario

The BAU scenario has been developed based on the historical trend of fuels used in different vehicles in Nepal. The energy demand and emission values are forecasted from LEAP, which provides future energy and emission projections for the BAU scenario. The energy consumption in this scenario has been predicted 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 Fig. 3.

The GHG emissions for the transportation sector in the base year are estimated at 4.10 mMTCO$_{2eq}$, calculated using a 100-year Global Warming Potential (GWP) as standardized by the Intergovernmental Panel on Climate Change. The GWP values applied are 1 for CO_2, 27 for CH_4, and 273 for N_2O, reflecting their relative climate impacts over a century. Projections indicate a CAGR of 4.45% until 2030, followed by a marginal increase to 4.56% through 2045 under the BAU scenario. GHG emissions from the transportation sector are projected to reach 11.39 mMTCO$_{2eq}$ by 2045, which represents a significant increase of 3 times compared to the baseline level recorded in 2022. The overall GHG emission in the BAU scenario is shown in Table

Table 4. GHG emissions in BAU scenario (mMTCO$_{2eq}$)

GHG	2022	2025	2030	2035	2040	2045
Carbon dioxide (CO_2)	3.95	4.52	5.6	6.99	8.81	11
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 CO$_{2eq}$	4.10	4.68	5.81	7.25	9.13	11.39

3.2.2 Sustainable Development Scenario

The 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 demand and emission values are forecasted from LEAP, which provides future energy and emission projections for the SD scenario. The energy consumption in this scenario has been predicted to reach 68.35 PJ by 2030 and 106.94 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 Fig. 4.

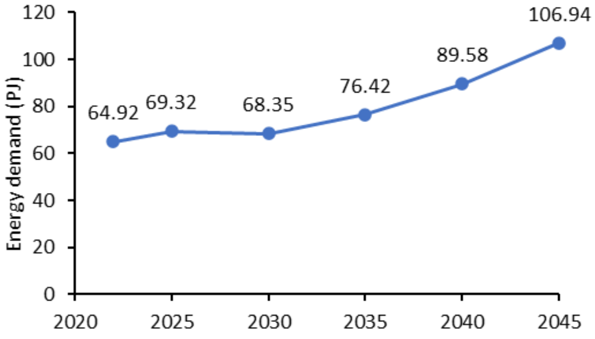

Fig. 4. Energy demand by the SD scenario

The GHG emissions in the base year for the transportation sector are estimated to be 4.10 mMTCO$_{2eq}$ at a 100-year GWP. Looking ahead, the sector's emissions are projected to experience a CAGR of -0.51% until 2030. Following this period, the emissions are expected to continue increasing at a slightly higher rate of 2.9 % until the year 2045. This data illustrates a rising penetration rate of electric passenger vehicle in the transportation sector until 2030 while the frieght vehicle will still be dependent on the fossil fuels. After 2030, the GHG will steaduily increase due to increasing numbers of frieght vehilces and most of the passenger vehicle converted to electric vehilces. The overall GHG emission in the SD scenario is shown in Table 5

Table 5. GHG emissions in SD scenraio (mMTCO$_{2eq}$)

GHG	2022	2025	2030	2035	2040	2045
Carbon dioxide (CO_2)	3.95	4.2	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 CO$_{2eq}$	4.10	4.35	4.27	4.74	5.52	6.55

3.2.3 Net-Zero Emission Scenario

The NZE scenario has been developed based on the NZE targets for the transportation sector by 2045. The energy demand and emission values are forecasted from LEAP, which provides future energy and emission projections for the NZE scenario. 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 Fig. 5.

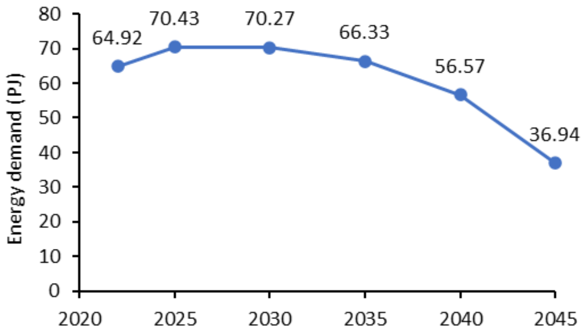

Fig. 5. Energy demand by the NZE scenario

The GHG emissions in the base year for the transportation sector are estimated to be 4.10 mMTCO$_{2eq}$ at a 100-year GWP. Looking ahead, the sector's emissions are projected to experience a 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 the NZE scenario is shown in Table .

Table 6. Green houses gas emission in NZE scenario (mMTCO$_{2eq}$)

GHG	2022	2025	2030	2035	2040	2045
Carbon dioxide (CO_2)	3.95	4.26	3.96	3.3	2.09	0
Methane (CH_4)	0.08	0.08	0.08	0.06	0.04	0
Nitrous Oxide (N_2O)	0.06	0.07	0.06	0.05	0.03	0
Total CO$_{2eq}$	4.10	4.41	4.10	3.42	2.16	0

3.3 Electric Vehicle in Nepal

The number of EVs 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 vehicles remain the same, the number of EVs (except freight vehicles) has been presented in Table .

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 the NZE 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 kilometres. This will reduce the total number of vehicles by 56%. The details of the vehicle numbers under the NZE scenario are presented in Table

Table 7. Vehicles number in different scenarios

Vehicle type	2025	2030	2035	2040	2045
BAU Scenario					
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
SD 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
NZE 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

Table 8. Electric vehicle with 75% passenger demand due to Bus/minibus in the 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

3.4 Impacts of EV Charging Point and Electricity Demand

The sustainable development scenario and the net zero emission scenario consider a large penetration of EVs, while the business-as-usual scenario considers the historical trend, i.e., a small penetration of EVs. 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 NZE scenarios. According to the Handbook for EV Charging, it has been recommended to consider public charging for 10% of electric motorcycles, e-rickshaws & tempos and 10%-25% of cars/jeeps/vans [39]. The electricity demand and charging point required as per business-as-usual, sustainable development, and NZE scenarios are shown in Table .

Table 9. Electricity demand and charging points

Vehicle	Electricity demand in GWh		Share of public charging	Number of chargers	
	2030	2045		2030	2045
BAU Scenario					
Car/Jeep/Van	40.51	133.04	10%	46	149
Motorcycle	2.84	9.34	17%	66	217
Tempo	2.34	4.40	20%	62	117
Microbus	4.94	9.31	25%	14	26
Bus/minibus	1.26	2.37	50%	2	3
E Rickshaw	9.65	18.17	20%	256	481
SD Scenario					
Car/Jeep/Van	640.51	1,776.47	10%	714	1,979
Motorcycle	275.68	773.79	17%	6,386	17,923
Tempo	14.77	71.94	20%	391	1,905
Microbus	40.41	127.56	25%	113	356
Bus/minibus	532.78	1,585.89	50%	609	1,811
E Rickshaw	9.65	18.17	20%	256	481
NZE Scenario					
Car/Jeep/Van	363.86	1,933.47	10%	406	2,154
Motorcycle	143.65	773.79	17%	3,328	17,923
Tempo	15.65	76.48	20%	415	2,025
Microbus	35.71	175.92	25%	100	490
Bus/minibus	400.55	2,164.74	50%	458	2,472
E Rickshaw	9.65	18.17	20%	256	481

The widespread adoption of EVs requires a substantial supply of electrical energy. In many countries, this demand is met primarily through petroleum or coal-based power generation, which is non-renewable and contributes to emissions. In contrast, Nepal has set an ambitious goal of generating 28,500 MW of electricity by 2035 from hydropower and other clean energy technologies, as outlined in its Electricity Development Roadmap [8]. The electricity demand and power plant capacity required to supply the electricity, under the assumption that the generated electricity is utilized throughout the scenario, are shown in Table.

Table 10. Electricity demand and power plant capacity

Scenario	2025	2030	2035	2040	2045
Energy demand in GWh					
BAU	40.92	61.53	89.49	127.65	176.62
SD	361.54	1,513.80	2,430.84	3,449.96	4,609.78
NZE	308.12	1,595.23	3,503.53	6,316.58	10,261.72
Power plant capacity in MW					
BAU	6.74	10.13	14.74	21.02	29.09
SD	59.54	249.31	400.34	568.18	759.19
NZE	50.74	262.72	577.00	1,040.28	1,690.01

4. CONCLUSIONS

The total energy consumption in the transportation sector in Nepal in 2022 is found to be 64.92 PJ, out of which diesel accounts for 60.48%

followed by petrol, LPG and electricity at 38.94%, 0.46% and 0.11%. In regard to the vehicle type, motorcycles consumed 30.31% followed by tractors at 19.72%, 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 CAGR of 4.55% in the BAU scenario and reach 180.46 PJ by 2045, whereas in the SD scenario, the energy demand will increase at 2.19% and reach 106.94 PJ, and in the NZE scenario, the energy demand will increase at a CAGR of -2.42% and reach 36.94 PJ by 2045.

GHG in the transportation sector, initially measured at 4.10 mMTCO$_{2eq}$ in the base year 2022. By 2030, GHG are projected to reach 5.81 mMTCO$_{2eq}$,, 4.27 mMTCO$_{2eq}$, and 4.10 mMTCO$_{2eq}$, in BAU, SD and NZE scenarios respectively. Similarly by 2045, these levels are projected to be 11.39 mMTCO$_{2eq}$, and 6.55 mMTCO$_{2eq}$ for the BAU and SD scenarios while the NZE scenario achieves complete elimination of emissions.

The electricity demand to support the growing number of EVs is projected to reach 176.62 GWh, 4,609.78 GWh, and 10,261.72 GWh by the year 2045 under the BAU , SD and NZE 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 EVs in Nepal will reach 134,880, 7,084,646, and 7,152,286 by 2045 in the BAU, SD and NZE scenarios respectively. Under the NZE scenario, if the 75% passenger demand is fulfilled by the bus/minibus, the number of EVs by 2045 will reduce by 56%. The number of charging points in the BAU, SD and NZE scenarios required to sustain the increasing demand of EVs will reach 993, 24,455 and 25,545 by 2045, respectively.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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