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# Impact of Electric Vehicle on Energy Demand in Nepal Using a Scenario-based Approach

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**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) will put a strain on the existing electrical infrastructure, as EVs require electricity to charge their batteries. This study aims to assess the impact of EVs on the electricity demand in the Nepal. The study found that the overall energy consumption in the road transportation sector of Nepal was 64.92 petajoules (PJ) in 2022.Similarly, the GHG emission in the base year amounted for 4.10 $mMTCO_2eq$. In regards to the fuel consumed, Diesel accounted for the majority of energy consumption (60.48%), followed by petrol (38.94%), LPG (0.46%), and electricity (0.11%). Motorcycles were the largest energy consumers, accounting for 30.31% of the total. Under the business-as-usual scenario, the consumtion of electricity due to penetration of EVs is projected to reach 0.22 PJ by 2030 and 0.64 PJ by 2050. This will lead to an increase in the overall energy demand to 180.46 PJ by 2045 ans the GHG emission to 11.39 $mMTCO_2eq$. In the Sustainable Development scenario, the overall energy demand is projected to reach 106.94 PJ by 2045 and the overall GHG emission will reach 6.65 $mMTCO_2eq$. This is because the mass penetration of EVs is limited to the passenger vehicles in the sustainable development scenario as guided by the sustainable development scenario. In the Net-Zero Emission scenario, the overall energy demand is projected to reach 36.94 PJ by 2045 and will reach net zero emission by 2045. This is because the mass adoption of EVs for both passenger vehicle and freight vehicles. Overall, the study found that the penetration of EVs will have a significant impact on the electricity demand in the Nepal.

**Keywords**
Energy, Energy modelling,Energy demand, Electric Vehicle, Service demand projection

## 1. Introduction

The number of vehicles registered in Nepal by 2022/23 has reached 5,260,161 and has increased at an compound annual growth rate (CAGR) of 17.38% over the last five years [1]. 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%. 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. In FY 2021/22, Nepal spent NPR 292.77 billion on imported petroleum products, witnessing an 88.7% increase compared to the previous year [2]. In recognition of the benefits of the electric vehicle, 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 fifteenth Periodic Plan. In addition the Government of Nepal has also been providing incentives the use of electric vehicles through tax exemptions, subsidies etc.

The population and the GDP of the country is the key drivers for energy demand in the country. As per the National Population and housing Census 2021 report, Nepal is experiencing a consistent rise in its population, with an annual growth rate of 0.92% [3]. 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. Water and Energy Commission Secretariat has iterated the Government plans and policies to further increase the GDP growth rate around 8% by 2045 [4].

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.[5] analyzed the population and GDP elasticity for passenger vehicles to be 1.44 and 0.41, respectively, and a GDP elasticity of 0.6 for freight vehicles. [6] utilized the Model for Analysis of Energy Demand (MAED) and forecasted that the energy demand within the transportation sector will increase by 5.5 times, 6.9 times and 8.6 times respectively in low, medium and high growth scenario. Similarly [7] estimated that private passenger vehicles consumed 55% of the total energy, i.e. 816 ktoe, used in road transport. [8] projections suggested that electrifying road transportation by 10% until 2020 would result in a cumulative real GDP increase of 2.8% spanning from 2005 to 2050. Similarly, [9] predicted that in the absence of carbon dioxide ($CO_2$) restrictions, the transportation sector's cumulative $CO_2$ emissions would reach 27% from 2005 to 2100, whereas scenarios involving emission reduction could lower this proportion to 6% and 9%. Similarly, [10] highlighted that a 20% reduction in the average liter gasoline equivalent (Lge) per 100 km was achieved from 2005 to 2016. [11] indicated that vehicular emissions, with $CO_2$ as the primary contributor, amounted to 7.23 million tonnes per year. [12] emphasized that a 9% reduction in energy demand, $CO_2$, and

Particulate matter 10 ($PM_10$) can be achieved by increasing the fuel efficiency by 30%. Similarly, [13] determined that adhering to Euro III standards for all vehicles could lead to a 44% reduction in toxic air pollutants and a 31% decrease in climate-forcing emissions compared to the baseline scenario. Moreover, [14] studied the emission factors for different fuels used in different economic sectors.

The growing penetration 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 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. The objective of the study is to project the increase in energy and electricity demand based on the government commitments and target based on the second Nationally determined contribution and the long term strategy for net zero emission.

# 2. Methodology

## 2.1 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 [15] as indicated below:

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

Where,

$\chi^2$= $\chi$ 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 $n_r$

## 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 with specific purposes in mind. The collected energy data were then aggregated 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.

$$\begin{aligned}&\text{Annual Energy Consumption of Vehicles, } E_x \\ &\quad = \text{Quantity of fuel per month} \\ &\qquad \times \text{calorific value} \\ &\qquad \times \text{number of operating days}\end{aligned} \tag{2}$$

$$\begin{aligned}&\text{Specific energy consumption} \\ &\quad = \frac{1}{n}\sum(\mathrm{E}_x), \text{where x denotes different samples}\end{aligned} \tag{3}$$

$$\begin{aligned}&\text{Total energy consumption of vehicle types} \\ &\quad = \sum \text{Specific energy consumption} \times \text{no. of vehicles}\end{aligned} \tag{4}$$

## 2.3 Development of Energy Model and Scenarios

### 2.3.1 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 [5],

$$\begin{aligned}&\text{service demand of nth year} \\ &\quad = \text{service demand of base year} \times \left(\frac{\text{GVA of nth year}}{\text{GVA of base year}}\right)^{\alpha 1} \\ &\quad \times \left(\frac{\text{Population of nth year}}{\text{Population of base year}}\right)^{\alpha 2}\end{aligned} \tag{5}$$

Where,
$\alpha 1$ is elasticity for GVA,
$\alpha 2$ is elasticity for population.

### 2.3.2 Energy Model Development

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.

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.

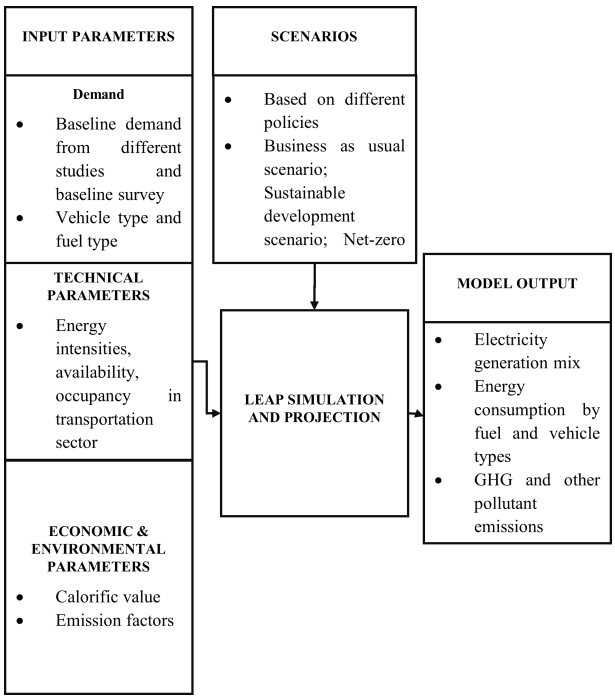


**Figure 1:** LEAP modelling framwork

## 3. Result and Discussion

### 3.1 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. 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 outcome of the survey is consistent with [16] which estimates the energy consumption in transport sector to be 67.10 PJ with the contribution od diesel at 60.34%.The overall energy consumption in the transport sector by fuel types is shown in Figure 2.

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.

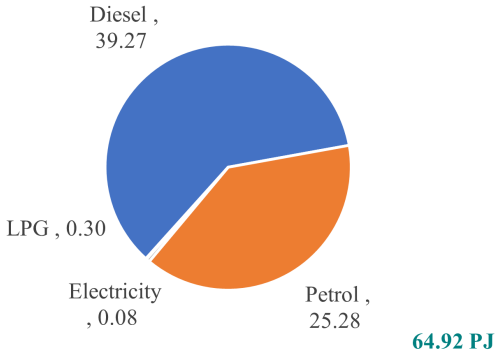


**Figure 2:** Energy consumption segregated by fuel type

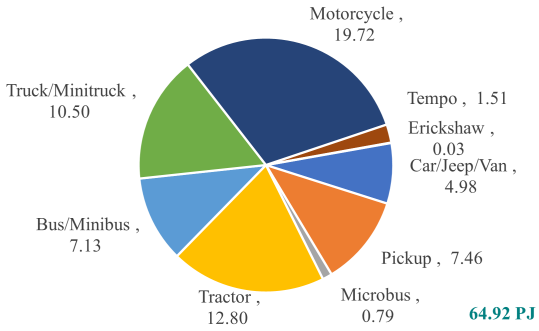


**Figure 3:** Energy consumption segregated by vehicle type

### 3.2 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 details of the growth rate in different scenarios are shown in Table 1.

**Table 1:** Population and GDP growth rates

| Scenario | 2022-2025 | 2026-2030 | 2031-2035 | 2036-2040 | 2041-2045 |
|---|---|---|---|---|---|
| Population | 1.19 % | 0.93% | 0.77% | 0.69% | 0.56% |
| GVA | 6.7 % | 7.5% | 8.0% | 8.5% | 8.3% |

### 3.3 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.

## 3.4 Business as Usual Scenario

### 3.4.1 Total Energy Consumption

The business as usual (BAU) scenario has been developed based on the historical trend of fuels used in different vehicles. 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 are shown in Figure 4.

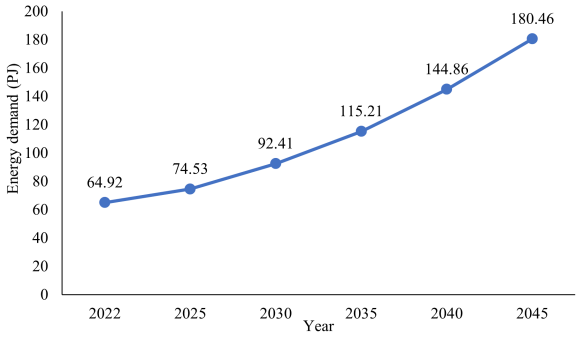


**Figure 4:** Energy consumption for Business as Usual Scenario

The greenhouse Gases (GHG) emission in the base year for the transportation sector is estimated to be 4.09 mMTCO_2eq (million metric tonnes of carbon dioxide equivalent) at 100 year global warming potential (GWP). The majority share in the GHG emission is due to carbon dioxide ($CO_2$) (3.95 mMTCO_2eq) followed by methane ($CH_4$) ( 0.08 mMTCO_2eq) and nitrous oxide ($N_2O$) (0.06 mMTCO_2eq) in the base year as shown in Table 2. 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.

**Table 2:** GHG emission (mMTCO_2eq) for Business as Usual scenario

| GHG | 2022 | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| $CO_2$ | 3.95 | 4.52 | 5.60 | 6.99 | 8.81 | 11.00 |
| $CH_4$ | 0.08 | 0.10 | 0.12 | 0.15 | 0.18 | 0.22 |
| $N_2O$ | 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 |

### 3.4.2 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 3. 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 3:** Energy projection by fuel type (PJ) for Business as Usual scenario

| 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 | 0.41 | 0.44 | 0.54 | 0.67 | 0.82 |
| Total | 64.92 | 74.53 | 92.41 | 115.21 | 144.86 | 180.46 |

## 3.5 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

### 3.5.1 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 consumption for different years are shown in Figure 5.

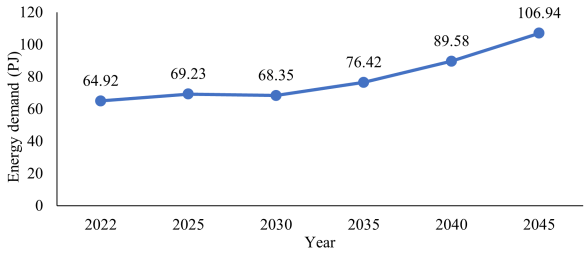


**Figure 5:** Energy consumption for Business as Usual scenario

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. 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. The total energy consumption for different years are shown in Table 4.

**Table 4:** GHG emission (mMTCO_2eq) for Sustainable Development Scenario

| GHG | 2022 | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| $CO_2$ | 3.95 | 4.20 | 4.16 | 4.64 | 5.42 | 6.44 |
| $CH_4$ | 0.08 | 0.08 | 0.05 | 0.03 | 0.02 | 0.02 |
| $N_2O$ | 0.06 | 0.07 | 0.06 | 0.07 | 0.08 | 0.09 |
| Total | 4.10 | 4.35 | 4.27 | 4.74 | 5.52 | 6.65 |

### 3.5.2 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%. This increase in electricity demand and simultaneous decrease in petrol and LPG consumption can be attributed to the widespread adoption of electric vehicles, as pledged in the Nationally Determined Contributions (NDC) towards achieving sustainable development goals. The overall energy consumption by fuel type is shown in Table 5.

**Table 5:** Energy projection by fuel type (PJ) for sustainable development scenario

| 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 |

## 3.6 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

### 3.6.1 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 consumption for different years are shown in Figure 6.

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 GHG emission in NZE Scenario is shown in Table 6.

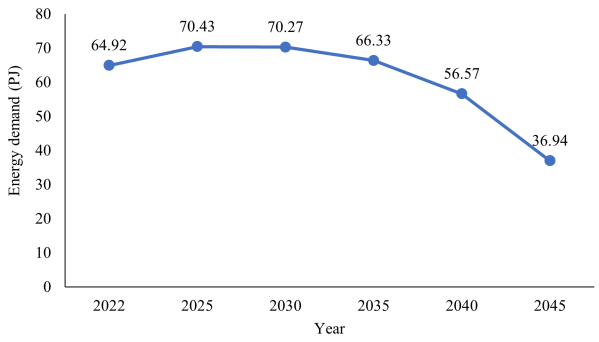


**Figure 6:** Energy consumption for Net-zero emission scenario

**Table 6:** GHG emission for Net Zero Emission Scenario

| GHG | 2022 | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| $CO_2$ | 3.95 | 4.26 | 3.96 | 3.30 | 2.09 | 0.00 |
| $CH_4$ | 0.08 | 0.08 | 0.05 | 0.03 | 0.04 | 0.00 |
| $N_2O$ | 0.06 | 0.07 | 0.06 | 0.07 | 0.03 | 0.00 |
| Total | 4.10 | 4.41 | 4.10 | 3.42 | 2.16 | 0.00 |

### 3.6.2 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 7.

**Table 7:** Energy projection by fuel type (PJ) for Net-zero emission scenario

| 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 | 0.15 | - | - |
| Total | 64.92 | 70.43 | 70.27 | 66.33 | 56.57 | 36.94 |

## 3.7 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 in the transportation sector is shown in Table 8.

**Table 8:** Electricity demand in transportation sector (GWh)

| Scenario | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|
| Business as Usual | 40.92 | 61.53 | 89.49 | 127.65 | 176.62 |
| Sustainable development | 631.54 | 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 |

## 4. Conclusion

The total energy consumption in transportation sector Nepal is found to be 64.92 PJ out of which the diesel accounts for 60.48% followed by petrol, LPG and electricity at 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 CAGR 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 overall electricity required to sustain the increasing amount of electric vehicle will reach 176.62 GWh, 4,609.78 GWh and 10,261.72 GWh in 2045 in business as usual scenario, sustainable development scenario and net zero emission scenario.

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