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Lifecycle Cost and Carbon Emissions Evaluation of Electric and Gasoline Vehicles in Kathmandu: A Case Study of the TATA Nexon

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Abstract

The rising global concern about greenhouse gas emissions and the economic burden of fossil fuels underscores the need for sustainable transportation solutions, particularly in densely populated cities like Kathmandu. The main aim of the study is to evaluate the cost efficiency and environmental impact of electric vehicles (EVs) compared to internal combustion engine vehicles (ICEVs) in Kathmandu Valley, focusing on and using a case of the TATA Nexon XZ+ models in both petrol and electric variants. The analysis involved calculating the Total Cost of Ownership per kilometer (TCO/km) and CO_2 emissions, using data from the Nepal Oil Corporation for fuel prices and the Nepal Electricity Authority for electricity tariffs. A detailed economic cost model was used, which included the initial purchase costs, ongoing operational expenses, and maintenance fees and all these costs were adjusted to reflect their value in today's terms by discounting them to present values. A sensitivity analysis was conducted to investigate how variations in annual kilometers traveled and initial purchase prices impact the total cost of ownership per kilometer (TCO/km). The findings reveal the EV variant offers a lower TCO/km, achieving savings of Rs. 22.6 per km, primarily due to lower fuel and maintenance costs. Environmentally, EVs offer substantial benefits by eliminating tailpipe emissions, a major contributor to CO_2 emissions from petrol vehicles.

Keywords: Greenhouse Gas Emissions, Electric Vehicles, Internal Combustion Engine Vehicles, Total Cost of Ownership

1. Introduction

The global transportation sector is a significant contributor to greenhouse gas (GHG) emissions, with global CO_2 emissions from the sector growing by over 250 Mt CO_2 to almost 8 Gt CO_2 in 2022, marking a 3% more than in 2021 (International Energy Agency, 2022), a growing concern worsened by rising urbanization and vehicle use. Densely populated cities are particularly vulnerable, leading to more frequent and severe extreme heat events (Bornstein and Lin, 2000). A substantial shift towards environmentally friendly transportation alternatives is essential (IPCC, 2022). For centuries, fossil fuels have been the primary energy source for transportation globally, and the continuation of this trend will drive up oil demand, making it increasingly unaffordable and consequently elevating transportation costs (Pathak and Subedi, 2021).

Research consistently reveals that Kathmandu's air quality is severely compromised, with (Particulate Matter) PM_{10} concentrations exceeding national standards on most days along busy roadsides (Raut, 2003; Saud and Paudel, 2018; Environmental Protection Agency, 2023). Real-time air quality data from Kathmandu shows spikes in PM_{10} and $PM_{2.5}$ concentrations, 29.8 times more than the World Health Organization's (WHO) annual air quality guideline, during peak traffic hours (Kathmandu Air Quality Index (AQI) and Nepal Air Po224llution | IQAir, 2024). The combined PM from diesel and gasoline vehicles contributes significantly to $PM_{2.5}$ in an urban environment (Gertler, 2005). In rapidly developing cities like Kathmandu, where vehicle fleets are expanding, decarbonizing the transportation sector is crucial for mitigating emissions, improving air quality and public health, enhancing energy security, and reducing reliance on imported petroleum (MoFE, 2021).

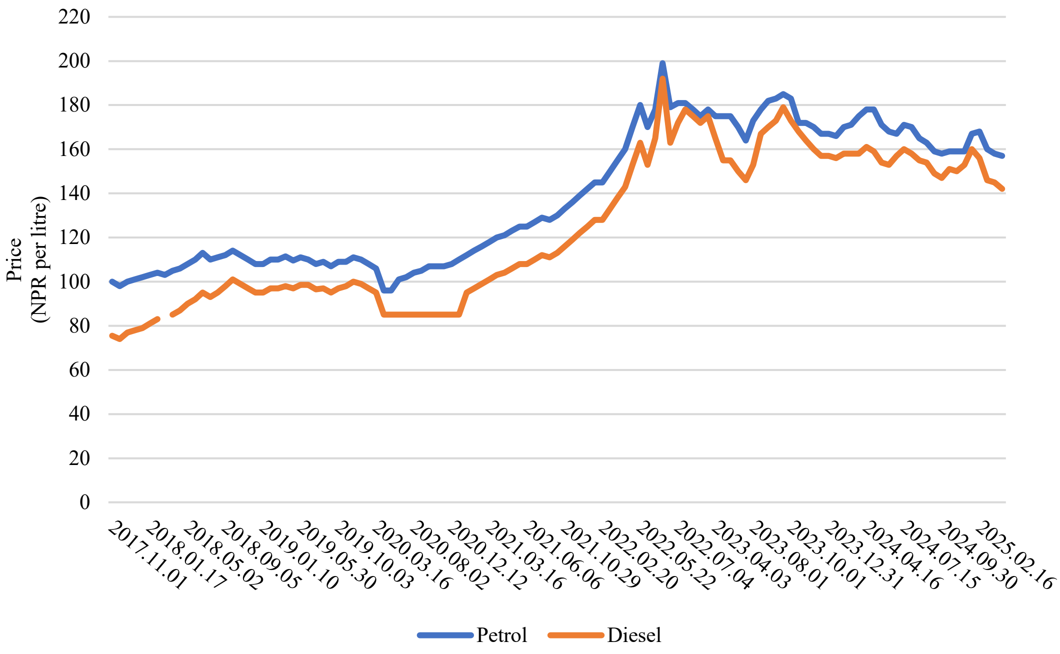
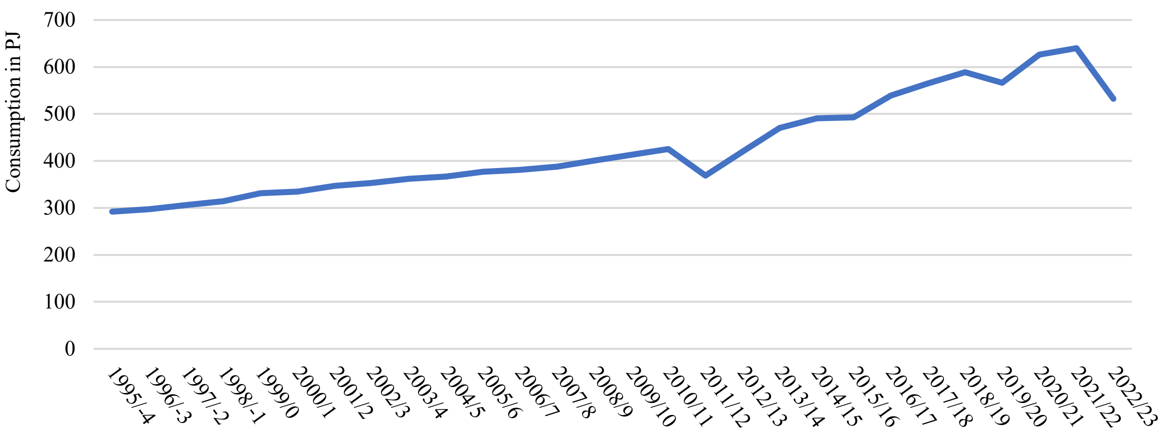


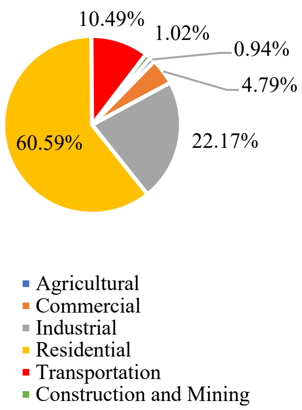
Figure 1. Price of petrol and diesel in Nepal, figure reproduced based on the data from reference (Nepal Oil Corporation, 2025)

Despite the urgency to decarbonize transportation, Nepal's reliance on fossil fuels for this sector is significant (Karn et al., 2023). In Nepal, this economic burden is compounded by the transportation sector's significant energy consumption, primarily fueled by petroleum products, thereby increasing the nation's vulnerability to volatile global oil prices and rising environmental concerns ('Energy Synopsis Report, 2023', 2023). The increase in the price of petrol and diesel in Nepal is depicted in Figure 1. Nepal's exclusive reliance on India for petroleum imports, coupled with existing energy supply-demand imbalances, price volatility in the petroleum market, and a lack of diversified energy sources, poses significant challenges to the nation's economic stability and energy security (Darlamee and Bajracharya, 2021), as transportation sector consumes a substantial percentage of the energy which is obtained from fossil fuels as shown in Figure 2 and Figure 3. In Nepal, discussions regarding alternative fuels to replace petroleum invariably resurface with each announcement of a price increase. However, identifying a suitable substitute for petroleum remains an enduring challenge (Sharma and Shrestha, 2023).



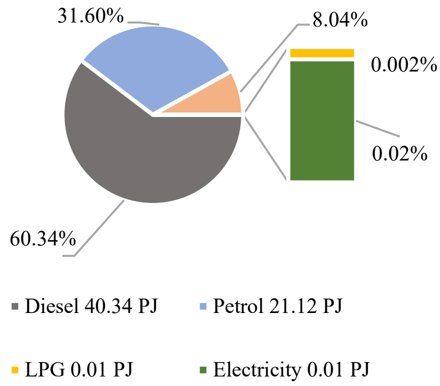
(Source: 'Energy Synopsis Report, 2024', 2024)

Figure 2. Total energy consumption throughout the year



(Source: 'Energy Synopsis Report, 2023)

Figure 3. Sectoral Energy Consumption



(Source: 'Energy Synopsis Report, 2023)

Figure 4. Energy Consumption by Fuel Types Transportation

The most important contributor to Kathmandu's air pollution is vehicular emissions, and the use of vehicles in the city is rising, as shown in Figure 5. One way of tackling the pollution problem is by promoting zero-emission electric vehicles (EVs) (Dev Bhatta with Dilli and Joshi, 2004). Nepal's electricity grid, primarily powered by hydropower, makes EVs zero-emission within the city. Kathmandu's suitability for EVs is further bolstered by its compact size (20-30 km cross section), low traffic speeds, and the urgent need to address air pollution (Raut, 2003). With the increasing availability of charging infrastructure, there exists potential for a shift toward electric mobility (Paudel et al., 2021). A comprehensive assessment of the co-benefits associated with electrifying the transport sector in Nepal revealed that achieving a 35% electrification target by 2050 would necessitate a 495 MW expansion of hydropower capacity (Shakya and Shrestha, 2011).

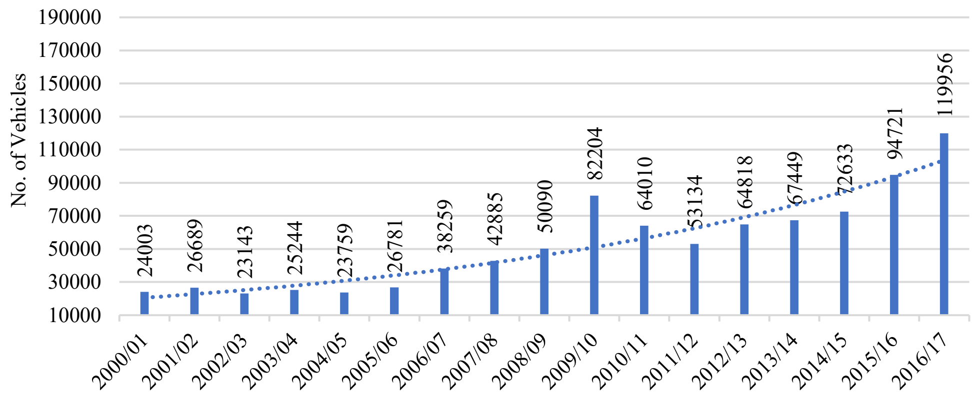


Figure 5. Number of Registered Vehicles in Kathmandu Valley, figure reproduced as per the data from reference (Paudel et al., 2021)

However, this investment would yield substantial returns, including a 14.6% reduction in energy imports and a 12.9% decrease in greenhouse gas emissions, equivalent to 74.7 million tons of CO_2e between 2015 and 2050 (Shakya and Shrestha, 2011). Despite the substantial positive aspects of EVs, most people are hesitant to shift towards this step over the conventional Internal Combustion Engine Vehicle (ICEV) primarily due to policy changes (The Kathmandu Post, 2023), inadequate infrastructure, higher upfront cost (The HRM Nepal, 2023), concerns about battery life and performance (Ratopati, 2023), and lack of awareness about the financial and environmental benefits of EV (OnlineKhabar English News, 2023).

From these studies, it is evident that Nepal has its clean energy source for EVs, which gives a promising tendency to be more economical to the owners, with its positive impact on the environment and sustainable development, than ICEV, operated in Kathmandu Valley. Hence, a combined economic and environmental study of gasoline versus electric vehicles is crucial to inform policies promoting EVs adoption in Nepal. This study aims to help reduce fossil fuel dependency, mitigate adverse environmental impacts, and contribute to economic growth and a cleaner environment. Therefore, this study will comprehensively analyze the cost and environmental impact of electric vehicles (EVs) and internal combustion engine vehicles (ICEVs) in Kathmandu Valley, comparing their Total Cost of Ownership per kilometer (TCO/km) and CO_2 emissions. The research will provide a detailed assessment of the economic and environmental implications of both vehicle types, contributing to informed decision-making regarding sustainable transportation options in the region.

2. Materials and Methods

2.1 Data acquisition

The situation and trends of fuel prices, energy consumption, electricity tariffs, trends of use of private vehicles, as well as rules and regulations with a focus on taxes within the area of Kathmandu Valley was taken under consideration. For the study of the cost of petrol in Nepal, data from the website of NOC was extracted (Nepal Oil Corporation, 2024). The cost of the petrol and diesel corresponding to their date was compiled into a spreadsheet and then the graph showing the cost pattern and fluctuation of them was plotted against the date and the cost per unit of electricity in Nepal was accessed through NEA tariff rates (Nepal Electricity Authority, 2024).

2.2 Total cost of ownership (TCO) per kilometer calculation model

For the calculation of the cost of operation, TCO/km is done. The total TCO was divided by the total distance traveled in kilometers to calculate TCO/km. Also, taking into consideration of the time value of money, any future costs are discounted to their present values. TCO/km was calculated using the model represented by equation 1 (Wu, Inderbitzin and Bening, 2015):

$$\frac{TCO}{km} = \frac{(IPC - RV \times PVF) \times CRF + \left(\frac{1}{N}\right) \sum_{n=1}^{N} \frac{(AOC)}{(1+i)^n}}{AKT} \qquad \text{(Equation 1)}$$

Where, TCO/km = the total cost of ownership per kilometer [Rs. per km]

IPC = the initial purchase cost of the vehicle [Rs.]

RV = Resale Value

PVF = Present Value Factor

CRF = capital recovery factor

N = lifetime of the vehicle (years)

AOC = annual operating cost of the vehicle

i = discount factor

AKT = annual kilometer travel

The value of CRF was calculated by using Equation 2 (Wu, Inderbitzin and Bening, 2015):

$$CRF = \frac{i(1+i)^N}{(1+i)^N - 1} \qquad \text{(Equation 2)}$$

The capital cost was calculated by subtracting the present value of future resale value (RV) from IPC, which was annualized by the CRF with the view of spreading the cost of the vehicle throughout, for ownership, incorporating the discount rate. The AOC incorporates the time value of future payments by taking consideration of discount rate. The obtained value of annual cost was then divided by AKT. The parameters IPC, RV, AOC, and AKT were all dependent on the type of vehicle and the use case scenario. This study compares the petrol and electric versions of the TATA Nexon XZ+. All relevant data on these vehicles were obtained from Tata Motors Nepal’s official sources. To assess the robustness of the model, sensitivity analysis was performed on key input variables such as the Initial Purchase Cost (IPC) and Annual Kilometers Traveled (AKT).

2.3 Parameters and assumptions for TCO/km calculation

The parameters affecting the cost of EV and ICEV are listed below. The calculations were based on the assumption that the vehicle would operate within the Kathmandu Valley for its entire lifetime (Bajracharya and Bhattarai, 2016). The discount rate, total period of ownership, residual value factor, and per unit electricity rate were assumed as per current governmental policies (Pathak and Subedi, 2021). The data with AKT in Table 1 are assumed, as per the literatures, which are as follows:

Table 1. Parameters Set for the Analysis

AKT	12,310 km
Discount rate	10%
Total ownership period	10 years
Residual Value Factor	10.74%
Per Unit Electricity Price	Rs. 5.6
Per litre Petrol Price	Rs. 171

According to the warranty provided by manufacturers on its EV's battery from 4 years to 8 years for various models of EV (Tata Motors, 2021), for TATA Nexon XZ+, the battery replacement period was set at every fifth year of ownership. For both vehicles, the tire replacement period was considered to occur at four and eight years of ownership.

A discounted cash flow (DCF) model was constructed to evaluate the investment opportunity. It incorporates projections of both current and future cash flows. The average annual operating cost was calculated as AOC: (annual fuel/electricity cost + annual maintenance cost + annual tax + insurance). The annual maintenance cost per kilometer for different types of four-wheelers was found to be Rs. 0.3/km for EV variant and Rs. 1.5/km for ICEV variant (Pathak and Subedi, 2021).

2.4 Calculation of CO_2 emission

For the calculation of the amount of CO_2 emission, an Excel model was created. The US EPA (Environmental Protection Agency, 2023) and other agencies use the following carbon content value on average to estimate the CO_2 emissions:

Table 2. CO_2 emission from the tailpipe

CO_2 emission from the tailpipe	mton/litre
1 litre of petrol	0.0023
1 litre of diesel	0.002689

The following equations were used to calculate per liter and the life cycle CO_2 emission (Environmental Protection Agency, 2023):

$$\mathrm{CO_2\ emission\ per\ km} = \frac{\mathrm{CO_2\ per\ liter}}{\mathrm{km\ per\ liter}} \qquad \text{(Equation 3)}$$

$$\mathrm{Life\ Cycle\ CO_2\ emission} = \mathrm{CO_2\ emission\ per\ km} * \mathrm{Total\ km\ travelled} \qquad \text{(Equation 4)}$$

3. Results

3.1 Total cost of ownership per kilometer

The calculation was based on the Tax and Tariffs in Kathmandu Valley. For the convenience of the study, TATA Nexon XZ+ (petrol) and TATA Nexon XZ+ (Electric) were taken. However, any vehicle can be used for the analysis. The result obtained from the spreadsheet model showed that the TCO/km of TATA Nexon XZ+ (petrol) is Rs. 73.07/km, and that of TATA Nexon XZ+ (Electric) is Rs. 50.41/km.

3.2 Sensitivity analysis

In order to analyze the effect of change in some input parameters in TCO/km, sensitivity analysis was done. The parameters AKT and IPC were changed, and the effect on TCO/km was obtained.

3.2.1 Annual kilometer travel

For TATA Nexon XZ+ Petrol and Electric, the following results were obtained:

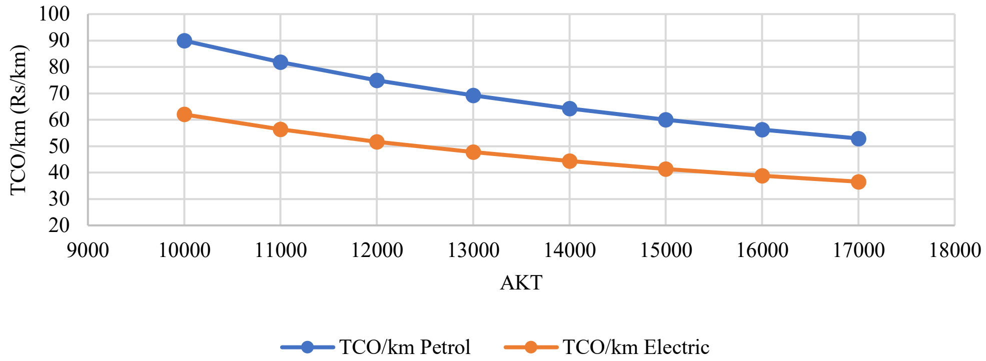


Figure 6. TCO/km for ICEV and EV for different AKT

The change in TCO/km with respect to AKT for both Electric and Petrol variants exhibits a similar pattern. At lower AKT values, the TCO/km is very high but decreases rapidly as the AKT increases.

3.2.2 Initial purchase price

With the change in IPC of the TATA Nexon XZ+ petrol variant, the following change in TCO/km was obtained:

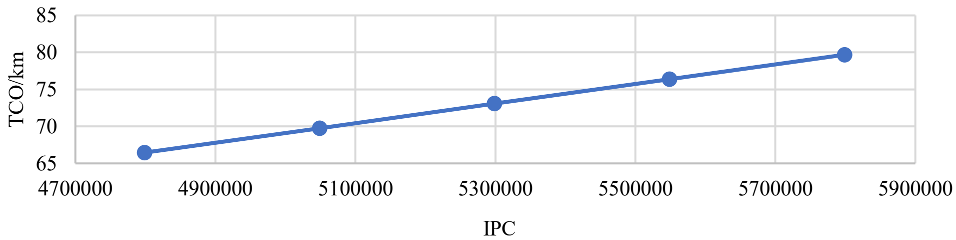


Figure 7. Change in TCO/km for different IPCs for ICEV

A similar analysis for the Electric variant was done, and the following change in TCO/km was found:

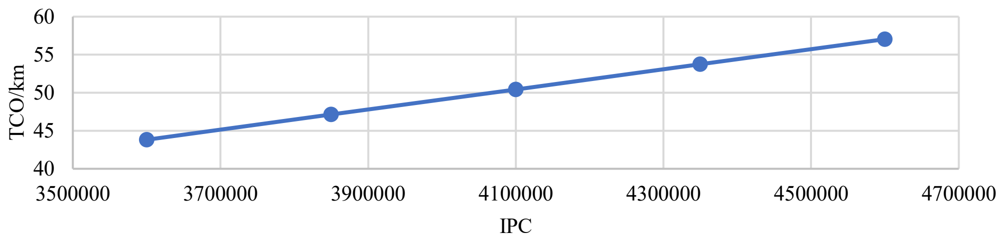


Figure 8. Change in TCO/km for different IPCs for EV

Both analysis results showed a directly proportional relationship between IPC and TCO/km, as an increase in one led to a corresponding increase in the other.

3.3 Calculation of carbon emission:

Table 3. Calculation of Carbon Emission

Total km run/day	Service Life (years)	life cycle run(km)	per liter CO_2 emission(mton)	mileage	petrol consumption (in liter)	Life Cycle CO_2 emission(mton)
40	10	140000	0.001102	17.5	8000	8.8184
45	10	157500	0.001102	17.5	9000	9.9207
50	10	175000	0.001102	17.5	10000	11.023
55	10	192500	0.001102	17.5	11000	12.1253

The obtained results indicate that life cycle CO_2 emissions rise as the daily distance traveled increases. This is because more petrol is consumed when a vehicle travels longer distances, resulting in higher CO_2 emissions. Electric Vehicles have zero tailpipe emissions.

4. Discussion

The study shows that the total cost of ownership per kilometer (TCO/km) for the electric variant of the TATA Nexon XZ+ is lower than that of its petrol variant, which was due to lower fuel and maintenance costs. This finding aligns with global trends highlighting the economic advantages of EVs over ICEVs in the long run. Sensitivity analysis further demonstrates that the TCO/km for both EV and ICEV decreases as the annual kilometer traveled (AKT) increases, suggesting that higher utilization of vehicles leads to better cost efficiency. Additionally, the analysis reveals that the initial purchase price impacts the TCO/km. The study also emphasizes the environmental benefits of EVs, as they produce zero tailpipe emissions, unlike petrol vehicles, which contribute significantly to carbon emissions. The calculation of life cycle CO_2 emissions for petrol vehicles further clearly shows the environmental impact of ICEVs, with emissions increasing proportionally with the distance traveled. This study provides mathematical support and narrows the study down to focus on Kathmandu Valley for the previous research on electric vehicles (EVs) (Dev Bhatta With Dilli and Joshi, 2004; Wu, Inderbitzin and Bening, 2015; Pathak and Subedi, 2021), providing a more clear understanding of EV economics through sensitivity analysis of TCO/km to factors like annual kilometer traveled and purchase price. The paper does this by incorporating an environmental impact assessment through life cycle CO_2 emissions analysis and updating the analysis with current data.

Future Research Directions: Future research could incorporate modeling scenarios with varying degrees of EV penetration in the valley, for instance, a gradual increase from the current level to 25% or 30% of total vehicles. This analysis could also assess the impact on the electricity grid, identifying potential challenges and opportunities for grid infrastructure upgrades to accommodate increased demand. Since, the price of electricity may vary with time, a separate sensitivity analysis can also be performed. Furthermore, while this study focuses on tailpipe CO_2 emissions, future research should expand the analysis to encompass the emissions of not only CO_2 but also other greenhouse gases and pollutants, such as methane, nitrous oxide (N_2O), and particulate matter, associated with vehicle production, maintenance, and disposal.

5. Conclusion

This study concludes that adopting electric vehicles (EVs) in Kathmandu Valley presents a compelling economic and environmental opportunity. The lower total cost of ownership per kilometer (TCO/km) of NPR 50.41 for the electric variant of the TATA Nexon XZ+ compared to NPR 73.07 for its petrol counterpart, a saving of NPR 22.6 per kilometer underscores the viability of EVs as a sustainable transportation solution in the region. Furthermore, the electric variant produces no tailpipe emissions, unlike the petrol variant, which has a substantial carbon footprint. Even a small increase of 15 kilometers to the daily driving distance (from 40 km/day) results in the petrol vehicle emitting an additional 3.3069 metric tons of CO_2 over its lifetime, further highlighting the environmental advantage of the electric vehicle. While current policy challenges and gaps in incentives for EVs remain a barrier, the economic and environmental benefits make a strong case for their adoption.

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