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Transitioning Sri Lanka's Transport Sector from Petroleum to Renewable Energy: A Comparative Evaluation of Solar and Wind-Powered Electric Mobility

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1 Introduction

The transportation sector plays a major role in economic and social development but remains a significant source of greenhouse gas emissions due to its reliance on petroleum-based fuels. In Sri Lanka, as in many developing nations, the transport system depends heavily on diesel and petrol, leading to high carbon footprints, energy insecurity, and worsening air pollution [1], [2]. Between 2000 and 2014, vehicle registrations increased from 1.69 million to 5.61 million (see **Figure 1**), primarily due to the rapid growth of three-wheelers and two-wheelers, indicating a clear shift from public to private transport and a corresponding rise in fuel consumption and emissions [3], [4].

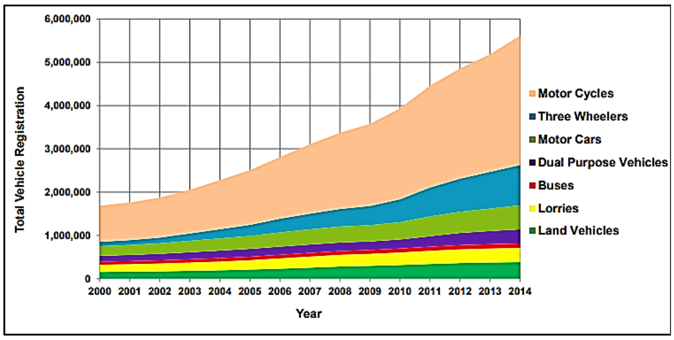

Figure 1. Trends in Sri Lanka's vehicle population by type (2000–2014). Adapted from T. Sugathapala, "Fuel Economy of Light Duty Vehicles in Sri Lanka: The Baseline," GFEI/UNEP, 2015.

This dependence not only contributes to environmental degradation but also exposes the national economy to fluctuations in global fuel prices. Consequently, transitioning toward renewable-powered transport systems has become vital for achieving long-term sustainability and climate resilience.

Existing research indicates that electric vehicles (EVs) powered by renewable sources such as solar and wind energy can significantly reduce emissions while enhancing energy security [1]. However, high initial infrastructure costs, limited charging networks, and inadequate public transport systems have slowed adoption in developing regions [2], [5]. Several studies emphasize the need for integrated, multi-modal transport solutions that combine electrified mobility with renewable energy integration [6], [7]. Despite this growing body of work, a clear research gap remains in systematically assessing the transition potential from petroleum to renewable energy within Sri Lanka's transport sector.

This study aims to measure current fuel consumption, fuel costs, and CO_2 emissions in Sri Lanka's transport sector, and to assess the renewable energy capacity, investment requirements, and emission-reduction potential associated with a shift toward solar- and wind-powered electric mobility.

2 Methodology

This study employed a structured methodology integrating literature review, quantitative data analysis, and scenario-based evaluation to assess petroleum consumption in Sri Lanka's transport sector and examine renewable energy-powered alternatives. A comprehensive literature review was first conducted to identify global and regional transport-energy trends, emission factors, policy instruments, and case studies on transitions toward electric and renewable-based mobility.

Figure 2 illustrates the methodological framework, and each step is summarized as follows:

Conduct literature review – Identify gaps in petroleum dependency, emission impacts, transport-sector energy trends, and the feasibility of renewable-powered mobility solutions.

Data gathering – Quantitative data were sourced from key government institutions, including the Department of Motor Traffic, Ceylon Petroleum Corporation, and the Sustainable Energy Authority, providing the basis for estimating vehicle-level fuel use, costs, and emissions.

Calculate fuel cost and emissions – Using the collected datasets, annual fuel consumption, total fuel expenditure, and CO_2 emissions for each vehicle category were estimated based on standard emission factors and fuel-use patterns. This enabled baseline assessment of petroleum dependency.

Estimate renewable energy capacity – Renewable energy requirements for powering an equivalent EV-based transport scenario were calculated using solar and wind resource data, system performance assumptions, and expected EV energy demand.

Calculate the cost of solar and wind systems for EVs – Using the calculated renewable energy capacity, the costs of generating EV charging energy through solar and wind installations were estimated, including system sizing, capital investment, operational costs, and lifetime energy yield.

Conduct financial and environmental comparison – The petroleum-based transport system was compared with a renewable-powered EV scenario using key performance metrics such as fuel cost, lifetime energy cost, CO_2 reduction potential, required renewable energy capacity, investment cost, payback period, and internal rate of return (IRR).

Develop recommendations – Based on the analytical outcomes, feasible strategies were proposed to support Sri Lanka's transition toward renewable energy–integrated mobility, emphasizing economic viability and emission reduction potential.

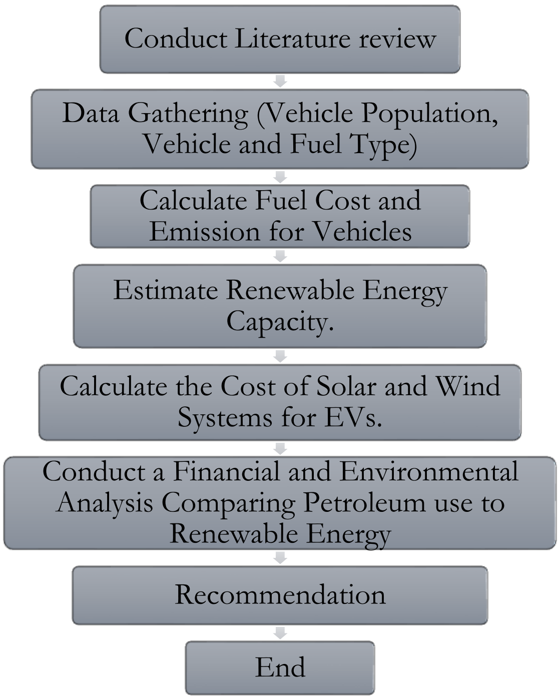

Figure 2. Flowchart.

3 Results and Discussion

3.1 Vehicle Population

Annual vehicle population statistics for 2012–2021 were obtained from published reports of the Department of Motor Traffic (DMT) (See **Figure 3**). Sri Lanka's vehicle fleet grew markedly between 2012 and 2021, covering motor cars, motor tricycles, motorcycles, and dual-purpose vehicles. Total registrations rose from 4.09 million to 7.36 million, a 79% increase [8]. Motorcycles showed the fastest growth, particularly from 2014 to 2018, while motor tricycles grew steadily but stabilized after 2019. Motor cars increased consistently from 2015 onwards, and dual-purpose vehicles showed moderate growth throughout the period.

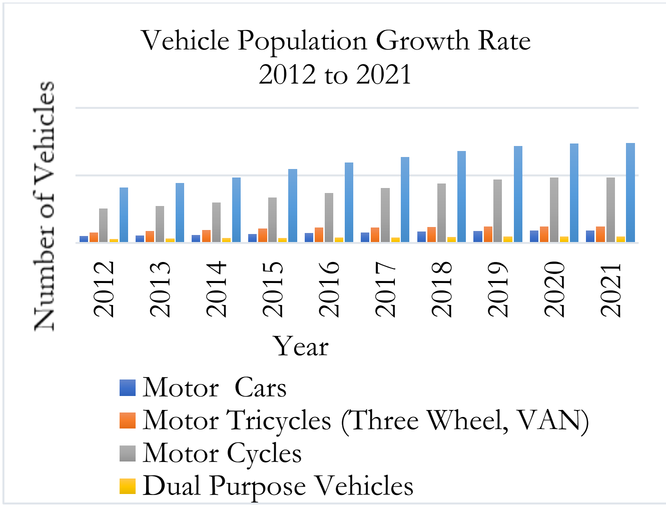

Figure 3. Vehicle population growth trends in Sri Lanka (2012–2021).

3.2 Vehicle Population 2021 to 2023

As consolidated annual totals were unavailable beyond 2021, the vehicle population for 2021–2023 was estimated by aggregating category-wise counts from the DMT's Monthly New Registration of Motor Vehicles dataset [8]. This method enabled consistent estimation across major categories, including motor cars, motorcycles, motor tricycles, dual-purpose vehicles, and other vehicle types, ensuring a continuous and reliable dataset for trend analysis up to 2023. During this period, Sri Lanka experienced a petroleum fuel crisis, which may have influenced vehicle registration patterns, particularly discouraging fuel-intensive vehicles while sustaining demand for motorcycles. **Figure 4** shows vehicle registrations, with motorcycles recording the highest growth and motor tricycles remaining stable. Overall, the total vehicle population rose gradually from 8.33 million to 8.35 million, indicating a consistent upward trend despite the fuel supply constraints.

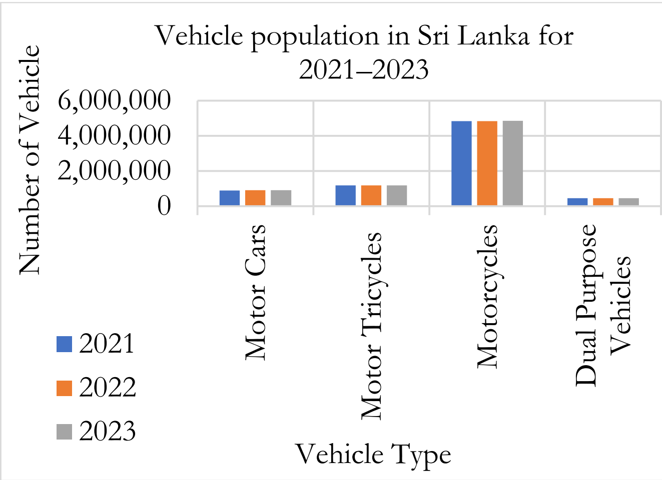

Figure 4. Vehicle population in Sri Lanka (2021–2023).

3.3 Solar Panel and Wind Capacity of Charge EVs

Based on calculated EV energy demand, the renewable energy capacity required to support an equivalent EV fleet was assessed using domestic rooftop PV and small-scale wind systems**.** Up to 2021, approximately 3,196 MW of solar or 2,179 MW of wind capacity would have been needed. Following the 2021–2023 petroleum fuel crisis, energy demand decreased, reducing the required capacity to 8.1 MW solar / 5.5 MW wind in 2022 and 5.3 MW solar / 3.6 MW wind in 2023.

Wind consistently required 30–40% less installed capacity than solar for the same EV charging demand, reflecting higher capacity factors. These results provide a practical benchmark for planning distributed renewable energy installations for transport electrification under varying travel and fuel availability conditions.

3.4 Analysis Comparing Petroleum Cost to Renewable Energy Cost up to 2023

The study evaluates fuel, solar, and wind energy costs and returns for EV charging from up to 2023. Up to 2021, fuel costs were LKR 459.72 billion, producing 7.59 million kg of CO_2, while solar installations for EV charging required LKR 479.44 billion with a 1.04-year payback and 56% IRR over 2 years, and wind energy cost LKR 348.68 billion with a 0.76-year payback. The findings indicate that petroleum consistently remained the most expensive and carbon-intensive option, whereas renewable energy particularly wind offered lower costs, shorter payback periods.

In 2022, fuel costs reached LKR 908.76 million, generating 5.73 million kg of CO_2, while solar installations for EV charging cost LKR 1.3 billion with a 1.43-year payback and 24.36% IRR over 2 years, and wind energy required LKR 938.88 million with a 1.03-year payback. The findings indicate that petroleum remained the most expensive and carbon-intensive option, whereas renewable energy particularly wind continued to offer lower costs, shorter payback periods. Solar installations, although slightly higher in cost than wind.

In 2023, fuel costs for EV charging reached LKR 943.13 million, generating 6.36 million kg of CO_2, confirming that petroleum remained the most expensive and carbon-intensive option. In comparison, solar installations for EV charging cost LKR 893.29 million, with a payback period of 0.95 years and a high IRR of 66.78% over 2 years, indicating strong investment potential. Wind energy required LKR 680.71 million, with a payback period of 0.72 years, also demonstrating good financial returns. These findings highlight that renewable energy both solar and wind offers more affordable and economically viable alternatives to conventional fuel.

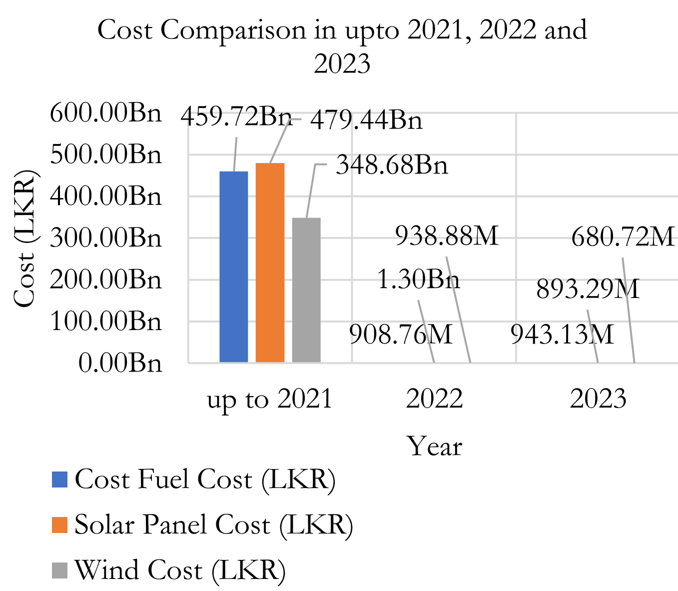

Figure 5. Comparative costs of fuel and renewable energy for vehicles (up to 2021, 2022, and 2023).

3.5 Discussion

Up to 2023, fuel costs for EV charging reached LKR 461.57 billion, generating 7.60 million kg of CO_2, indicating that petroleum continues to incur the highest cost and carbon emissions. Solar panel installations for EV charging cost LKR 481.62 billion, and wind energy required LKR 350.30 billion. The results show that renewable energy options reduce both operating costs and emissions compared with petroleum-based charging. Solar and wind also demonstrate greater cost stability across the years, whereas fuel costs fluctuated sharply due to price volatility and supply disruptions. The comparison further indicates that expanding renewable-based EV charging can significantly lower long-term national energy expenditure while supporting decarbonization goals. Solar installations, in particular, offer a practical pathway for widespread deployment in locations where wind infrastructure may not be feasible, enhancing accessibility to cleaner charging options across diverse regions.

4 Conclusions

The analysis of fuel costs, CO_2 emissions, and renewable energy requirements across vehicle types highlights the substantial financial and environmental burdens of continued petroleum dependence. While wind energy offers shorter payback periods and lower overall installation costs than solar, its deployment is constrained by geographic suitability, land availability, and larger infrastructure requirements. Solar energy, on the other hand, is easier to install, maintain, and integrate into existing buildings, making it a practical and scalable option for expanding EV charging networks, particularly in urban and densely populated areas. Its rooftop flexibility positions solar as the most feasible and accessible renewable energy option for supporting widespread transport electrification.

To enable a sustainable transition, targeted incentives should be introduced to promote renewable-powered vehicles, prioritizing solar-based charging infrastructure for its adaptability and ease of deployment. Investments in public transport, cycling, and pedestrian-friendly infrastructure can reduce reliance on private vehicles. Strengthening vehicle emission and fuel-efficiency standards, alongside programs that encourage replacing older vehicles, will help mitigate pollution and lower fuel demand. Urban planning that supports mixed-use development can reduce travel distances and transport emissions. Additionally, large institutions and government fleets should be supported through subsidies and guidance to adopt EVs powered by renewable sources, ensuring a coordinated, practical, and resilient shift toward a cleaner transport system in Sri Lanka.

Declaration of Competing Interest

The authors declare no competing interests.

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Credit Authorship Statement

Fathima Sharqa; Data Collection, Data Curation, Calculation, Data Comparison and Analysis, Interpretation of Results, Writing and Editing the Manuscript. **Tharanga Wickramarathna**; Supervision, Data Analysis, Review and Editing of the Manuscript. All authors have read and agreed to the published version of the manuscript.

Keywords

Transport sector, Electrical vehicle, Renewable energy, CO2 emission, Sustainable, Urban scalability.

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