VOL. 24, NO. 3, 2025, 328-336
elektrika.utm.my
ISSN 0128-4428

ELEKTRIKA
Journal of Electrical Engineering

Cost-Benefit Analysis of Owning an Electric Vehicle for a Residential Home with Solar PV under Malaysia's NEM Scheme

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Abstract: The transition to electric vehicles (EVs) is accelerating globally, driven by environmental concerns and energy cost savings. This paper evaluates the cost-benefit of replacing a petrol (gasoline) car with an EV for residential users in Malaysia under the Net Energy Metering (NEM) scheme. A comparative analysis is conducted using Excel-based model for households with different electricity consumption levels (300 kWh, 500 kWh, 700 kWh, and 900 kWh per month) and varying daily EV commutes (20 km to 100 km per day). The study considers an 80 kWh EV car charged solely at home, with and without rooftop solar photovoltaic (PV) systems (4 kWp and 10 kWp). Results indicate that for low to moderate household electricity consumption (≤500 kWh/month), EV ownership remains cost-effective compared to petrol cars, even without solar PV. However, for high energy users (>700 kWh/month), additional EV charging pushes electricity bills into higher tariff blocks, increasing costs. Installing a 4 kWp or 10 kWp solar PV system significantly reduces charging costs, with a 10 kWp system eliminating grid electricity expenses almost entirely. Meanwhile, household with 4 kWp can save at least 52.32% up to 100% depends on electricity and EV consumption. Sensitivity analysis further reveals that higher electricity tariffs can reduce the cost advantage of EVs without PV, while rising petrol prices improve EV savings. Additionally, improvements in EV efficiency and PV generation enhance financial returns, making EV-PV integration a more robust investment under varying market conditions. Without PV, the financial advantage of EVs depends on fuel price stability and electricity tariff rates. This analysis highlights that EV adoption is most cost-effective when combined with solar PV, aligning with Malaysia's energy transition goals.

Keywords: Electric Vehicle (EV), Cost-Benefit Analysis, Solar Photovoltaic (PV), Net Energy Metering (NEM), Residential Electricity Tariff

Article History: received 9 April 2025; accepted 25 June 2025; published 22 December 2025
Digital Object Identifier 10.11113/elektrika.v24n3.728

1. INTRODUCTION

The adoption of electric vehicles (EVs) has gained significant traction worldwide as countries transition toward sustainable and low-carbon transportation solutions. In Malaysia, government policies and incentives are encouraging EV adoption to reduce reliance on fossil fuels and align with the National Energy Transition Roadmap (NETR). However, the financial feasibility of EV ownership remains a key concern for residential users, particularly in terms of charging costs and the impact on household electricity bills.

One potential solution to mitigate EV charging costs is integrating rooftop solar photovoltaic (PV) systems under Malaysia's Net Energy Metering (NEM) scheme, which allows households to offset electricity consumption with self-generated solar power. Given Malaysia's abundant solar potential, pairing EVs with residential PV systems could provide significant cost savings, making EV ownership more attractive. However, the economic benefits of this approach vary depending on home electricity consumption, daily commuting distances, and PV system capacity.

This study aims to quantify the cost-benefit of EV ownership for Malaysian households by analyzing various scenarios, including:

i) Household electricity consumption levels before EV adoption (300 kWh, 500 kWh, 700 kWh, and 900 kWh per month).
ii) Daily EV driving distances (ranging from 20 km to 100 km).
iii) The impact of PV system sizes (4 kWp and 10 kWp) under the NEM scheme.
iv) A comparison with conventional petrol vehicle ownership, considering fuel costs and electricity tariffs.

By simulating realistic electricity and fuel cost scenarios, this paper provides insights into the financial feasibility of switching from a petrol type car to an EV while utilizing solar PV for home charging. The findings will help households, policymakers, and industry stakeholders understand the economic implications of EV adoption in Malaysia and assess the role of solar PV integration in reducing EV charging costs.

2. LITERATURE REVIEW

2.1 Malaysia's Electricity Tariff Structure

Malaysia's electricity tariff structure is designed to reflect the cost of electricity supply and promote efficient energy use. The tariffs are categorized based on consumer types—residential, commercial, and industrial—with residential tariffs structured in increasing blocks to encourage energy conservation. The block tariff mechanism (as applied to the residential tariff structure before 1st July 2025) incentivized energy efficiency by increasing the unit rate as consumption rose, making it a key factor when analyzing the financial viability of electric vehicle (EV) adoption and solar photovoltaic (PV) integration. Table 1 shows the tiered tariff system for residential consumers, where higher consumption levels were charged at progressively higher rates.

Table 1. Electricity tariff for domestic customers in Malaysia [1]

Tariff category	Current rate (cents/kWh)
For the first 200 kWh (1 – 200 kWh) per month	21.80
For the next 100 kWh (201 – 300 kWh) per month	33.40
For the next 300 kWh (301 – 600 kWh) per month	51.60
For the next 300 kWh (601 – 900 kWh) per month	54.60
For the next kWh (901 kWh onwards) per month	57.10

Minimum monthly charge is RM3.00

2.2 Net Energy Metering (NEM) Scheme in Malaysia

To promote renewable energy adoption, Malaysia introduced the Net Energy Metering (NEM) scheme in November 2016, allocating a 500 MW quota until 2020 [2]. Under this scheme, solar PV owners consume the electricity generated first, with any excess exported to the grid at the prevailing displaced cost. However, the initial uptake was low, with only about 3.4% (17 MW) of the quota utilized by 2018 [3].

In response, the government enhanced the scheme with NEM 2.0 in 2019, introducing a one-to-one offset mechanism for exported energy, making solar investments more attractive [4]. This policy revision significantly improved adoption rates, with approved capacity reaching 58.6 MW by mid-2019. Building on this progress, NEM 3.0 was introduced in 2021, extending the program until 2024 with a 500 MW quota and additional initiatives like NEM Rakyat, NEM GoMEn, and NOVA to cater to different consumer segments [5].

2.3 Electric Vehicle (EV) Adoption in Malaysia

In Malaysia, Electrical Vehicle (EV) registration was very encouraging in last 3 years. In 2021, total EV registration in Malaysia was 1058, increasing to 4308 in 2022. In 2023 and 2024, the registration was 15,669 and 28,048 respectively [6]. The numbers are expected to increase as the government has set the target to achieve 5% EVs by 2030 and 38% by 2040 of the annual total industrial volume (TIV) [7].

2.4 Integration of Solar PV and EVs: Related Studies

The study of integration of Solar PV and EVs has been developing for over a decade and will continue to develop in line with the development of EVs. Manousakis et al. [8] provides a comprehensive review of the integration of renewable energy sources (RESs) and electric vehicles (EVs) into power systems, analyzing their impacts, management strategies, and optimization techniques while identifying research gaps for future exploration. Li et al. [9] investigate the technical and economic feasibility of the Solar PV and Wind Turbine power system for environment-friendly EV charging station in China. Nunes et al. [10] explores the possible complementarities between wind and solar power and electric vehicles charging based on case study in Portugal. Bellocchi et al. [11] assesses the incorporation of electric vehicles into Italy's energy landscape and their interaction with renewable energy generation, examining the long-term effects on emissions, costs, and energy curtailments. Taibi et al. [12] evaluates how electric vehicles may influence production costs under various charging scenarios, while also exploring the potential benefits of enabling EVs to supply energy and ancillary services to the grid. Khan et al. [13] investigates the feasibility and design of a BIPV (building-integrated photovoltaic) powered EV charging system in a typical Malaysian house using solar energy to meet residential and EV charging demand. Roslan et al. [14] studies the techno-economic impacts analysis of renewable energy-based hybrid energy storage system integrated grid electric vehicles charging station (EVCS) in Malaysia. Mazlan et al. [15] examines the cost-effectiveness, environmental and technical aspects of a microgrid system that includes grid-connected solar panels, BESS and EV supply equipment (EVSE). Yang et al. [16] proposed an energy management strategy for PV-integrated energy storage (PV-ES) charging stations based on time-of-use (TOU) electricity pricing. The authors developed a comprehensive benefit analysis model that accounts for the interests of the charging station, the power grid, and society. The model was validated using a case study of a PV-ES charging station in Beijing. A study from Jeon et al. [17] proposed a stochastic dynamic programming approach to co-optimize household loads, EV charging, and distributed energy resources under NEM tariffs. A recent study from Das [18] addressed EV charging challenges in Bangladesh by proposing grid-tied EV charging stations powered by solar, wind, and lithium iron phosphate (LFP) batteries in three coastal cities. Irfan et al. [19] examined the integration of electric vehicles with grid-connected rooftop solar PV systems in Australian smart homes. The study emphasized that charging EVs with renewable energy is essential to maximize emission reductions and avoid stressing the power grid. A recent study from Elkadeem et al. [20] explored the resilience and economic benefits of microgrids (MGs) integrated with solar PV, batteries, and electric vehicles (EVs) for office facilities. The study assessed the impact of net energy metering (NEM) and demand response (DR) on MG performance, showing a 6.25% reduction in energy costs and a 6.43% decrease in electricity charges. A recent study from Shafiq et al. [21] conducted a techno-economic assessment of a grid-tied solar-based EV charging station in Pakistan to address the lack of charging infrastructure and high energy costs. The system significantly reduced energy costs from \$0.200/kWh to \$0.016/kWh and alleviated grid load by 254,030 kWh/year. Only 13% of the generated electricity was used for EV charging, with the surplus exported to the grid, generating additional revenue and highlighting the economic viability of renewable-powered charging solutions. Razali et al. [22] investigated the potential financial return of NEM schemes in term of net present cost and electricity cost savings in Malaysia.

2.5 Contribution of This Study

While previous studies have explored solar-powered EV charging stations and grid integration of EVs, limited research has specifically examined the cost-benefit of EV ownership for residential consumers under Malaysia's Net Energy Metering (NEM) scheme. Most existing studies focus on commercial or workplace EV charging, evaluate standalone solar PV systems without assessing their impact on EV charging costs, or discuss general EV adoption challenges without detailed cost comparisons between EVs and petrol cars under actual household energy consumption scenarios.

This study aims to bridge these gaps by conducting a financial analysis of switching from a petrol type car to an EV for Malaysian households. The study incorporates actual domestic electricity tariff structures and evaluates how increased electricity consumption due to EV charging affects overall household costs. Additionally, it assesses the economic impact of integrating rooftop solar PV (4 kWp and 10 kWp) under the NEM scheme with different monthly electricity consumption (300 kWh, 500 kWh, 700 kWh, and 900 kWh). This monthly electric consumption represents more than 70% of the residential consumption in a city in Malaysia [23]. Unlike previous research, this study provides a direct side-by-side comparison of total household energy costs (electricity + fuel), enabling homeowners to determine under what conditions EV adoption is financially beneficial.

3. METHODOLOGY

3.1 System Overview and Key Parameters

The analysis considers a typical Malaysian household with a monthly electricity consumption of 300 kWh, 500 kWh, 700 kWh, and 900 kWh before EV adoption. The household is assumed to charge an 80 kWh electric vehicle (EV) using a Type 2 home charger, with energy consumption of 0.15 kWh per km. The study evaluates five daily commuting distances: 20 km, 40 km, 60 km, 80 km, and 100 km per day.

The study also incorporates different solar PV capacities:

i) 4 kWp PV system (moderate residential installation)
ii) 10 kWp PV system (high residential installation)

According to SEDA's official guidelines, the NEM Rakyat scheme allows residential users to install PV systems up to 10 kWp for three-phase connections and up to 4 kWp for single-phase connections. These capacity limits are designed to optimize self-consumption and ensure grid stability [24].

Solar PV generation is estimated based on Malaysia's solar irradiation, assuming an average yield of 4 kWh/kWp/day. Under the NEM scheme, any excess energy generated offsets household electricity consumption at a 1:1 net energy metering rate. The analysis is conducted using Excel-based model to measure the percentage of monthly cost savings between the system configurations. The overall analysis process illustrates in block diagram in Figure 1.

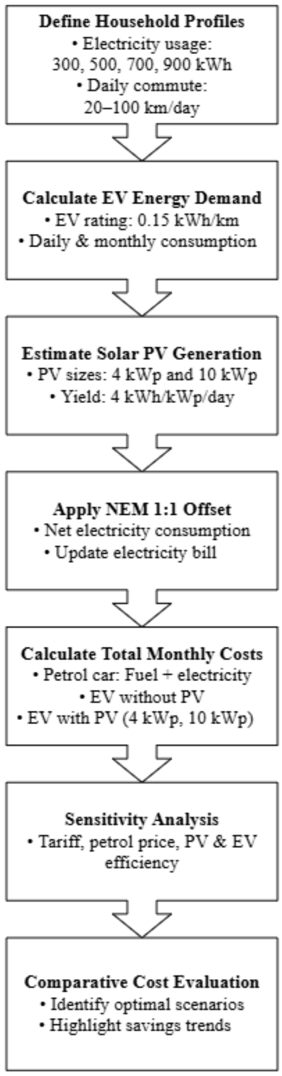

Figure 1. Block diagram of overall analysis process

3.2 Cost Calculation for EV Charging and Household Electricity Consumption

For each scenario, the total household electricity consumption, including EV charging, is calculated. The post-EV electricity bill is then determined using Malaysia's domestic electricity tariff structure, which follows a tiered pricing system. If a household has a solar PV system, the net electricity consumption after self-generation and NEM offsetting is used to compute the revised electricity bill. The monthly household electricity cost is derived as:

$$Monthly\ Household\ Consumption \times Electricity\ Tariff \tag{1}$$

The monthly EV charging cost is derived as:

$$\{\{Daily\ Distance \times 0.15/kWh/km \times 30\} + \{Monthly\ Household\ Consumption\}\} \times Electricity\ Tariff \quad (2)$$

For households with solar PV, the cost reduction due to solar generation is applied before calculating the final electricity bill.

3.3 Cost Calculation for Petrol Type Vehicle

For comparison, the cost of using a conventional petrol car is estimated using an average fuel consumption rate of 6.5 L/100 km and a petrol price (Ron95) of RM2.05 per liter. The monthly fuel cost is computed as:

$$\{Daily\ Distance \times 6.5\ L/100\ km \times 30\} \times RM\ 2.05/L \quad (3)$$

3.4 Comparison of Total Household Energy Costs

For each scenario, the total monthly household energy cost is evaluated under three conditions:

i) Petrol Car (Pre-EV scenario): Monthly electricity bill + fuel cost
ii) EV Without Solar PV: Monthly electricity bill after adding EV charging costs
iii) EV With Solar PV (4 kWp and 10 kWp): Monthly electricity bill after NEM offsetting

3.5 Assumptions and Limitations

This analysis is based on a set of simplifying assumptions to enable a focused evaluation of the cost-benefit implications of electric vehicle (EV) adoption under Malaysia's Net Energy Metering (NEM) scheme. Firstly, the NEM scheme is assumed to operate on a 1:1 energy offset basis, whereby any excess electricity generated by the rooftop solar photovoltaic (PV) system fully offsets grid electricity consumption in terms of cost. Secondly, the study excludes battery energy storage systems; thus, all solar energy is either self-consumed or exported to the grid under the NEM arrangement.

A constant petrol price of RM2.05 per litre is assumed throughout the analysis period, with no consideration for future fluctuations in fuel prices. The cost analysis is limited to operational expenses, specifically electricity and fuel costs, and does not account for capital expenditures related to EV purchases, PV system installation, or maintenance.

In terms of energy consumption, EV efficiency is assumed to remain constant at 0.15 kWh/km, which reflects the average performance of the top five EV models registered in Malaysia between January and April 2025 [6, 25]. The fuel efficiency of petrol vehicles is fixed at 6.5 litres per 100 km, based on the average consumption of several mid-range vehicles with engine displacements ranging from 1.5 L to 2.0 L of engine capacity [26]. No adjustments are made for performance degradation over time in either EV or petrol vehicle efficiency.

3.6 Sensitivity Calculation

Sensitivity analysis will be conducted based on the changes of electricity tariff, petrol price, PV and EV efficiency towards monthly cost. The analysis will be based on user with 900 kWh/month home consumption and 100 km daily commute.

4. RESULTS AND DISCUSSION

4.1 Results

Table 2 presents a comparative analysis of total monthly costs for households operating an EV, with and without a solar PV system, accounting for both electricity bills and transportation expenses. The results provide valuable insights into the financial implications of EV charging under different energy consumption scenarios. As expected, the total cost is highest when relying entirely on grid electricity without PV, particularly for households with higher energy demands and longer daily commutes. Conversely, integrating a 10 kWp PV system significantly reduces costs and, in most cases, eliminates additional EV-related electricity expenses entirely.

For households with a monthly electricity consumption of 300 kWh, it will cost from RM156.95 to RM475.75 for 20 km and 100 km daily commute respectively by using petrol car as shown in Table 2 (a). Meanwhile, transitioning from a petrol vehicle to an EV without PV results in an increased total cost, ranging from RM123.44 for a 20 km daily commute to RM313.70 for 100 km with saving percentage compared to no EV monthly cost from 21.35% to 34.20% respectively. While a 4 kWp PV system provides some cost reduction at higher energy usage levels up to 85%, the most significant savings come with a 10 kWp PV system, which fully offsets EV charging costs. This trend continues across higher consumption levels of 500 kWh, 700 kWh, and 900 kWh, where a larger PV system substantially lowers the financial burden associated with EV ownership.

At 500 kWh monthly consumption, petrol car user cost ranging from RM260.16 up to RM579.95 for daily commute from 20 km to 100 km as shown in Table 2 (b). Meanwhile, total costs for an EV car without PV range between RM226.64 and RM424.15 with cost saving percentage from 12.88% to 26.86% respectively, depending on the daily commuting distance. The 4 kWp PV system provides moderate savings, bringing costs down to RM23.98 for a 20 km commute and RM164.72 for 100 km with cost saving percentage of 90.78% and 71.60% respectively. However, the 10 kWp PV system completely offsets EV charging costs, making it the most effective option for cost reduction. The financial benefits of PV integration become even more pronounced as electricity consumption increases. At 700 kWh, total costs of using petrol by car increase up to RM686.15 and an EV car without PV rise to RM538.35 for a 100 km commute with 21.54% of cost saving, while the 4 kWp PV system reduces this to RM270.02 with 60.65% of cost saving of as shown in Table 2 (c). Again, the 10 kWp PV system completely eliminates additional EV charging costs.

For households with the highest consumption of 900 kWh per month, total costs having a petrol car and an EV without PV reach RM795.35 and RM652.55 for a 100 km commute respectively, the highest among all scenarios as shown in Table 2 (d). Even with a 4 kWp PV system, expenses remain significant at RM379.22 (52.32% cost saving). However, the 10 kWp PV system effectively mitigates these costs, reducing them to just RM32.70 (95.89% cost saving). Notably, for an 80 km commute under this consumption level, the 10 kWp PV system brings the total cost down to RM13.08, suggesting a near balance between PV generation and household load. The results are summarised and illustrated in Figure 2.

Overall, the analysis demonstrates that while EV adoption increases household energy costs, integrating a sufficiently large PV system, particularly a 10 kWp setup, can nearly eliminate these additional expenses. A 4 kWp system offers some relief but is less effective for households with higher consumption and longer commutes. For homeowners considering the transition to EVs, investing in a larger PV system presents a financially viable solution that not only reduces costs in the long term but also decreases reliance on grid electricity, supporting a more sustainable energy future.

Table 2. Total monthly costs for households operating an EV, with and without a solar PV system

(a) Home Consumption: 300 kWh/month

Daily Commute (km/day)	No EV			With EV				Percentage Saving (With EV against No EV)		
	Petrol Cost (RM)	Electricity bill (RM)	Total Monthly Cost (RM)	EV Monthly Consumption (kWh)	Total Monthly Cost (RM)					
					No PV	With 4kWp PV	With 10kWp PV	No PV	With 4kWp PV	With 10kWp PV
20	79.95	77.00	156.95	90	123.44	0	0	21.35%	100.00%	100.00%
40	159.90	77.00	236.90	180	169.88	0	0	28.29%	100.00%	100.00%
60	239.85	77.00	316.85	270	216.32	19.62	0	31.73%	93.81%	100.00%
80	319.80	77.00	396.80	360	264.56	39.24	0	33.33%	90.11%	100.00%
100	399.75	77.00	476.75	450	313.70	66.98	0	34.20%	85.95%	100.00%

(b) Home Consumption: 500 kWh/month

Daily Commute (km/day)	No EV			With EV				Percentage Saving (With EV against No EV)		
	Petrol Cost (RM)	Electricity bill (RM)	Total Monthly Cost (RM)	EV Monthly Consumption (kWh)	Total Monthly Cost (RM)					
					No PV	With 4kWp PV	With 10kWp PV	No PV	With 4kWp PV	With 10kWp PV
20	79.95	180.20	260.15	90	226.64	23.98	0	12.88%	90.78%	100.00%
40	159.90	180.20	340.10	180	275.48	43.60	0	19.00%	87.18%	100.00%
60	239.85	180.20	420.05	270	324.62	73.66	0	22.72%	82.46%	100.00%
80	319.80	180.20	500.00	360	373.76	118.28	0	25.25%	76.34%	100.00%
100	399.75	180.20	579.95	450	424.15	164.72	0	26.86%	71.60%	100.00%

(c) Home Consumption: 700 kWh/month

Daily Commute (km/day)	No EV			With EV				Percentage Saving (With EV against No EV)		
	Petrol Cost (RM)	Electricity bill (RM)	Total Monthly Cost (RM)	EV Monthly Consumption (kWh)	Total Monthly Cost (RM)					
					No PV	With 4kWp PV	With 10kWp PV	No PV	With 4kWp PV	With 10kWp PV
20	79.95	286.40	366.35	90	335.54	82.16	0	8.41%	77.57%	100.00%
40	159.90	286.40	446.30	180	384.68	128.60	0	13.81%	71.19%	100.00%
60	239.85	286.40	526.25	270	435.57	175.04	0	17.23%	66.74%	100.00%
80	319.80	286.40	606.20	360	486.96	221.48	0	19.67%	63.46%	100.00%
100	399.75	286.40	686.15	450	538.35	270.02	0	21.54%	60.65%	100.00%

(d) Home Consumption: 900 kWh/month

Daily Commute (km/day)	No EV			With EV				Percentage Saving (With EV against No EV)		
	Petrol Cost (RM)	Electricity bill (RM)	Total Monthly Cost (RM)	EV Monthly Consumption (kWh)	Total Monthly Cost (RM)					
					No PV	With 4kWp PV	With 10kWp PV	No PV	With 4kWp PV	With 10kWp PV
20	79.95	395.60	475.55	90 kWh	446.99	185.36	0	6.01%	61.02%	100.00%
40	159.90	395.60	555.50	180 kWh	498.38	231.80	0	10.28%	58.27%	100.00%
60	239.85	395.60	635.45	270 kWh	549.77	280.94	0	13.48%	55.79%	100.00%
80	319.80	395.60	715.40	360 kWh	601.16	330.08	13.08	15.97%	53.86%	98.17%
100	399.75	395.60	795.35	450 kWh	652.55	379.22	32.70	17.95%	52.32%	95.89%

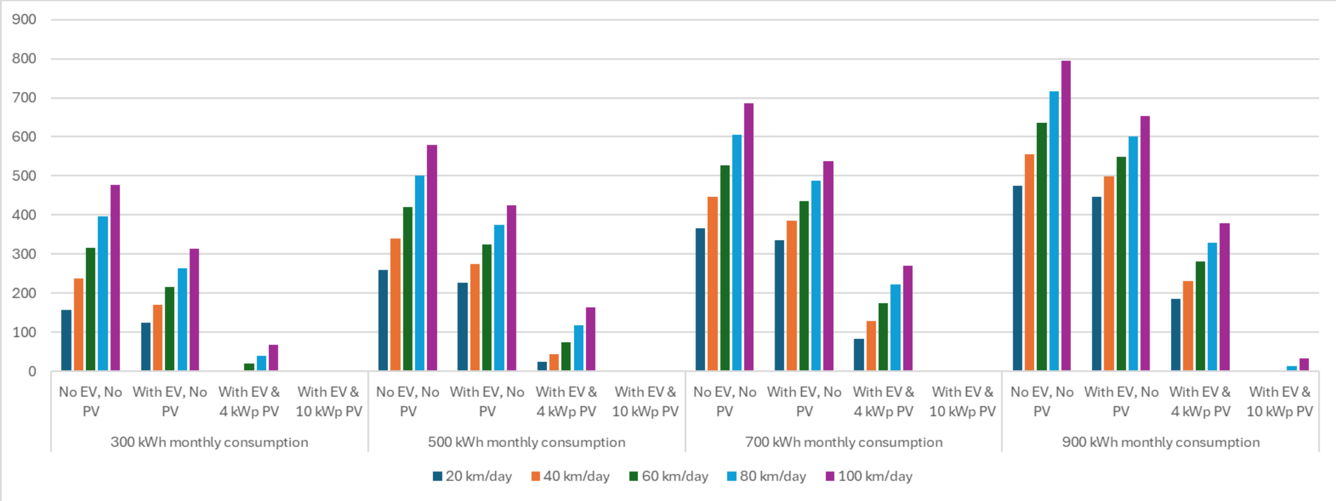

Figure 2. Monthly Household Costs (Petrol + Electricity bill) for Different Consumption Levels and EV Daily Commutes, with and without Solar PV Systems

4.2. Sensitivity Analysis

The sensitivity analysis results are presented in separate line charts in Figure 3, distinguishing between scenarios without PV and those with a 10 kWp PV system. This analysis examines the impact of key variables—electricity tariff, petrol price, PV efficiency, and EV efficiency—on total costs, providing deeper insights into the financial feasibility of EV adoption under different conditions.

4.2.1 Electricity Tariff Sensitivity

As expected, rising electricity tariffs lead to higher total costs in both scenarios. As shown in Figure 3, when electricity tariffs increase by 100%, both monthly cost for EV without PV and EV with 10 kWp increase by 100%. However, the impact is significantly more pronounced in the no-PV case, where EV charging is fully reliant on grid electricity. In contrast, for households with a 10 kWp PV system, the effect is minimal since solar generation offsets most of the electricity consumption, shielding EV owners from tariff fluctuations.

4.2.2 Petrol Price Sensitivity

The results correctly reflect that increasing petrol prices have no direct impact on EV operating costs. Instead, the rising petrol price only affects the total cost of ownership for petrol vehicles, making EVs a more attractive alternative. As shown in Figure 3, the total monthly cost can increase up to 22% when the petrol price is increase to RM2.5/L. However, for EV users without PV, savings depend on electricity tariffs. With a 10 kWp PV system, the advantage of EV ownership remains strong regardless of petrol price fluctuations, further highlighting the economic benefits of pairing EVs with solar PV.

4.2.3 PV Efficiency Sensitivity

Improvements in PV efficiency enhance cost savings for EV owners utilizing solar power. A higher-efficiency PV system generates more electricity per installed capacity, increasing the available solar energy for self-consumption. As shown in Figure 3, the total monthly cost can increase up to 104% when the PV efficiency is reduced by 10%, particularly in the 10 kWp PV scenario. In contrast, for households without PV, changes in PV efficiency have no impact on total costs, emphasizing the importance of PV adoption for maximizing EV-related savings.

4.2.4 EV Efficiency Sensitivity

Increasing EV efficiency index (i.e., achieving higher km/kWh) increases total costs in both scenarios, as a more efficient EV consumes less energy per kilometer, lowering electricity consumption. The impact is particularly significant in the no-PV case, where all electricity consumption is subject to grid tariffs. In the PV scenario, improved EV efficiency further reduces reliance on grid electricity, maximizing cost savings by utilizing more self-generated solar power. As shown in Figure 3, the total monthly cost can save up to 7.88% and 60% for EV without PV and EV with 10 kWp respectively when the EV efficiency is improved to 0.12 kWh/km.

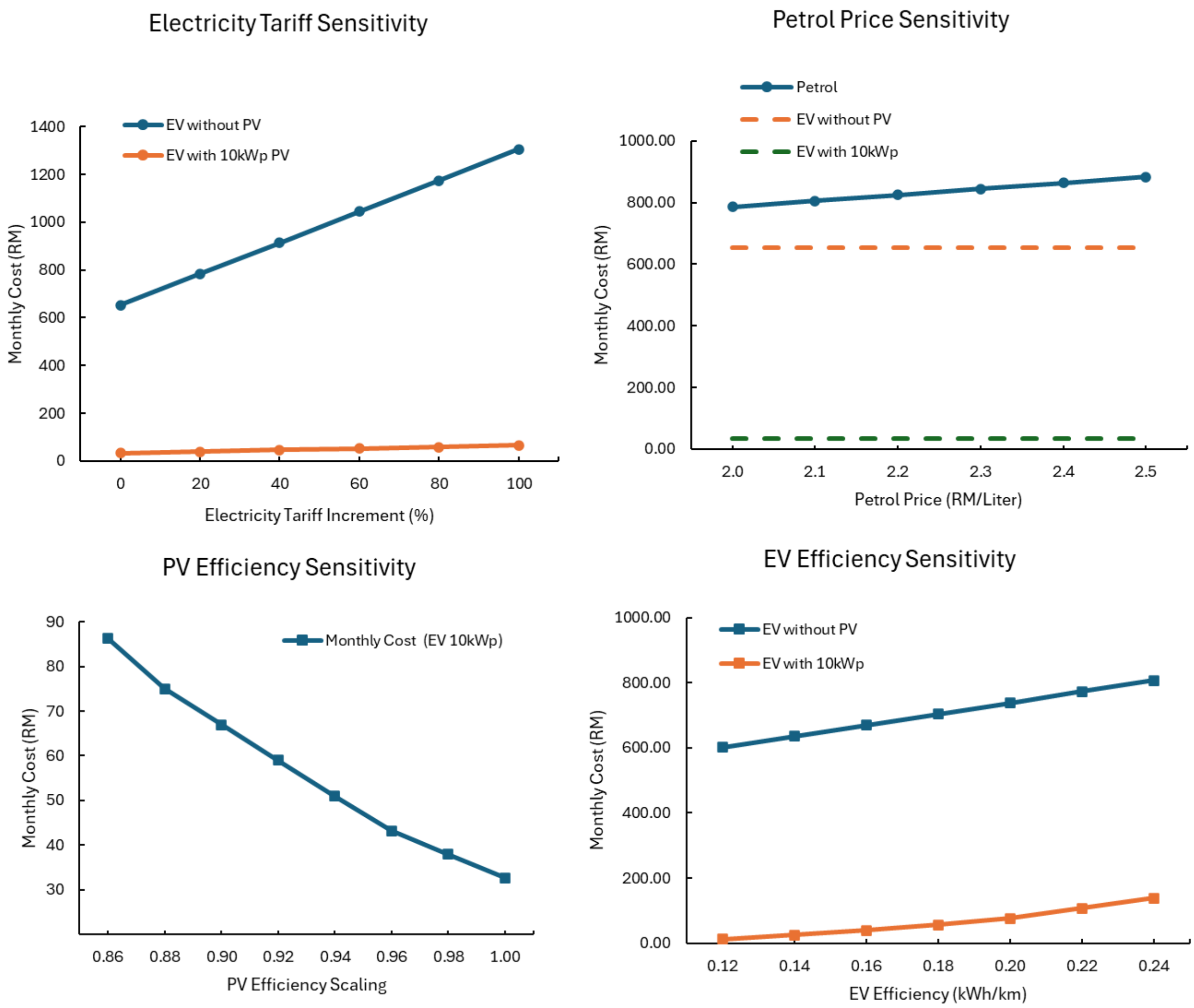

Figure 3. Sensitivity Analysis of Total Cost Impact for Key Variables (Electricity Tariff, Petrol Price, PV Efficiency, and EV Efficiency)

5. CONCLUSION

This study evaluates the cost-benefit implications of replacing a petrol type car with an electric vehicle (EV) in a Malaysian residential setting, considering different household electricity consumption levels, daily commuting distances, and solar PV system sizes under the Net Energy Metering (NEM) scheme. The results show that while EV adoption leads to higher household electricity consumption, the overall cost savings from eliminating petrol expenses make the transition financially viable, particularly for higher-mileage users. However, the sensitivity analysis reveals that these financial benefits are subject to key external factors, including electricity tariffs, petrol prices, PV efficiency, and EV efficiency.

The integration of solar PV significantly enhances the financial benefits of EV ownership. Households with a 10 kWp PV system experience the greatest cost reductions, often offsetting a substantial portion of their electricity consumption through self-generation. Even with a smaller 4 kWp system, notable savings are observed, although the benefits are less pronounced compared to the larger system. In contrast, households without PV rely entirely on grid electricity for EV charging, resulting in higher overall costs, particularly as EV charging pushes them into higher tariff blocks. This reinforces the economic advantage of pairing EVs with solar PV to minimize grid dependency and optimize long-term cost savings.

Sensitivity analysis further highlights the influence of fluctuating external factors on cost outcomes. An increase in electricity tariffs disproportionately raises costs for EV users without PV, making solar PV integration even more essential for maintaining cost savings. Conversely, higher petrol prices improve the financial appeal of EVs, particularly when combined with PV. Improvements in PV efficiency further reduce electricity costs for EV users, particularly in homes with high energy consumption. Additionally, EV efficiency plays a critical role, as more efficient EVs reduce energy demand, lowering overall electricity costs regardless of PV integration. These findings suggest that policy measures encouraging higher EV and PV efficiencies, alongside stable or preferential electricity tariffs for EV users, could further enhance the economic attractiveness of EV adoption.

The findings also highlight the importance of the NEM scheme, where the 1:1 net metering mechanism plays a crucial role in ensuring that residential solar PV investments remain financially attractive. Without NEM, the payback period for solar PV installations would be longer, reducing the incentive for homeowners to invest in clean energy solutions.

Despite providing useful insights into the economic benefits of EV adoption under the NEM scheme, this study is subject to several limitations that may affect its real-world applicability. The absence of energy storage modeling and the reliance on fixed household consumption patterns limit the ability to capture dynamic user behavior and load variability. These simplifications may result in over- or underestimation of cost savings in practical scenarios. Future research should incorporate time-varying tariffs, battery storage integration, and broader lifecycle cost considerations to enhance model realism and policy relevance.

Overall, the study demonstrates that transitioning to an EV, particularly when coupled with solar PV, can yield substantial financial benefits for Malaysian households. However, the extent of these benefits is highly dependent on external variables, including energy pricing, technology efficiencies, and government policies. Future research should explore additional factors such as battery storage integration, time-of-use (TOU) pricing, and potential changes in electricity and fuel policies that may further influence the economic feasibility of residential EV and solar PV adoption.

ACKNOWLEDGEMENT

This research was supported by the Centre of Electrical Energy Systems (CEES), Faculty of Electrical Engineering, Universiti Teknologi Malaysia. The authors would like to extend their gratitude for the facility support provided, which made this study possible.

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