IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(2), 392-406.

Analysing the Economic and Environmental Impact of Electric Vehicle Diffusion on the Malaysian Economy

Ismaily Johari[1]*, Nora Yusma Mohamed Yusoff[2]

[1]Universiti Tenaga Nasional, Kajang, Malaysia, [2]Institute of Energy Policy and Research, Universiti Tenaga Nasional, Malaysia.
*Email: ismailyjoe@gmail.com

Received: 02 July 2025 **Accepted:** 19 December 2025 **DOI:** https://doi.org/10.32479/ijeep.20846

ABSTRACT

The transition to electric vehicles (EVs) is increasingly viewed as a key strategy in decarbonising the transport sector, with far-reaching implications for national economies and energy systems. This study evaluates the macroeconomic, employment and environmental impacts of large-scale EV adoption in Malaysia using an environmentally extended input-output (EEIO) model. Two scenarios are evaluated for the different EV share targets (30%, 50% and 80%): (i) a shift in demand from petroleum to electricity due to EV use, and (ii) a structural transformation of the vehicle manufacturing sector from internal combustion engine (ICE) to EV. The results reveal modest benefits from fuel substitution alone, but larger gains from transitioning to EV manufacturing. However, the environmental gains remain limited without decarbonising the electricity mix. The study highlights critical trade-offs and emphasises the need for coordinated policy strategies linking transport electrification with clean energy deployment, labour market transition support, and green industrial development. These findings offer evidence-based guidance for managing Malaysia's low-carbon mobility transition in line with economic and climate policy objectives.

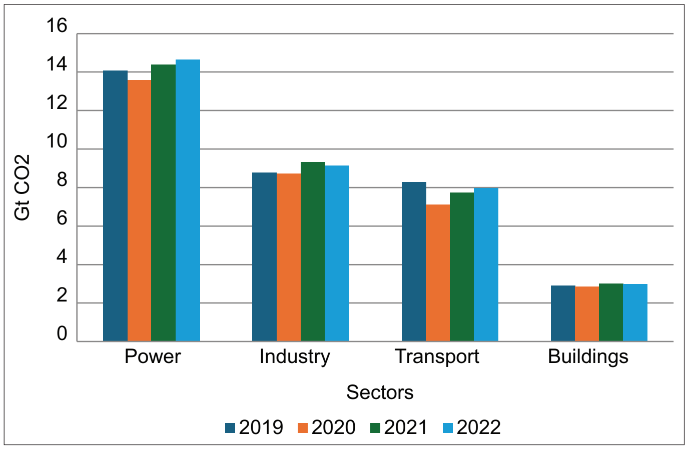
Keywords: Electric Vehicles (EVs), Input-Output Analysis, Energy Transition, Employment Impact, Green Manufacturing, CO2 Emissions, Low-Carbon Mobility, Environmental Policy
JEL Classifications: C6, Q4, Q5, J2

1. INTRODUCTION

The transportation sector significantly contributes to greenhouse gas (GHG) emissions, accounting for approximately 22% of global emissions (Figure 1), primarily from road transport (IEA, 2023). In line with the Paris Agreement's goal of limiting global warming to well below 2°C, countries are pursuing strategies to decarbonise transport and meet their nationally determined contributions (NDCs). Electric vehicles (EVs) have emerged as a pivotal solution in this context, given their potential to drastically reduce tailpipe emissions, improve urban air quality, and promote sustainable energy use (Eisenberg et al., 2020). By operating on electricity generated from renewable sources, EVs offer a clear alternative to internal combustion engine (ICE) vehicles, aligning with global climate mitigation and public health objectives (Agaton et al., 2020; Bistline et al., 2022; Hoehne et al., 2023).

EV deployment has accelerated rapidly in the past decade, though growth has been uneven across regions. Global EV sales reached record highs in 2023, with nearly 14 million electric cars sold, a 35% increase over 2022 and representing about 18% of global car sales (IEA, 2024). This record is a dramatic rise from just 120,000 EVs sold in 2012 and only 2% market share in 2019. However, the surge in EV uptake has been concentrated in a few significant markets. Approximately 95% of 2023 electric car sales occurred in China, Europe, and the United States. In contrast, emerging economies have seen slower EV diffusion due to higher vehicle

Figure 1: Global CO_2 emissions by sector, 2019-2022. (IEA, 2023)



costs, limited infrastructure, and policy barriers (Abas and Tan, 2024; Muzir et al., 2022).

The Malaysian Government has recognised the promise of electric mobility and introduced multiple initiatives to promote EV adoption. The National Automotive Policy (NAP) 2020 (Ministry of International Trade and Industry [MITI], 2020) explicitly prioritises next-generation vehicles, including EVs, aiming to position Malaysia as a regional hub for energy-efficient vehicles and EV manufacturing. The government has rolled out generous incentives for producers and consumers, such as import and excise duty exemptions for EVs and tax breaks for EV component manufacturers. Investment in charging infrastructure has also accelerated, where collaborations between the utility Tenaga Nasional Berhad (TNB) and private firms are expanding public charging networks in urban areas and highways. Also, Malaysia introduced the Low Carbon Mobility Blueprint (LCMB) 2021-2030 (Ministry of Environment and Water [KASA], 2021), a strategic framework aimed at reducing carbon emissions in the transport sector through EV adoption, cleaner fuels, and integrated mobility solutions to support its national climate goals and promote sustainable transportation. Furthermore, under the New Industrial Masterplan (NIMP) 2030 (Ministry of Investment, 2023), Malaysia positions EVs as a catalyst for industrial transformation, aiming to build a complete local EV ecosystem to drive economic growth, innovation and sustainability. These efforts reflect a high-level commitment to electrifying transportation. Malaysia has set ambitious targets for electric vehicle (EV) share of the total industry volume (TIV) as outlined in the National Energy Transition Roadmap (NETR), aiming for a 50% share by 2040 and an 80% share by 2050. Achieving these goals would significantly increase the market share of Battery Electric Vehicles (BEVs), currently at about 1.8% in 2023 (Malaysian Automotive Association, 2025). Such government targets, alongside plans for installations of more public charging stations, signal strong policy support for an EV revolution in the coming years.

Large-scale EV transitions pose significant challenges and potential unintended impacts, disrupting existing industries and labor markets despite their environmental and energy security benefits (Weng et al., 2024). Policymakers must manage this structural shift to maximize EV adoption's economic benefits while minimizing negative impacts on incumbent industries and workers. Another concern is the carbon footprint of EV production, especially lithium-ion battery manufacturing. Battery production is energy-intensive and involves mining and processing minerals like lithium, cobalt, and nickel, causing significant emissions and environmental degradation (Kurkin et al., 2024; Wang and Tang, 2022). Another critical issue is the electricity source for charging EVs. In Malaysia, fossil fuels dominate power generation, so increased EV charging demand could raise emissions at power plants. If the grid remains carbon-intensive, switching to EVs may reduce carbon dioxide (CO_2) emissions modestly or even negate them due to upstream emissions. Electrifying transport alone won't solve climate change without progress in clean energy. (Koniak et al., 2024; Leard and Greene, 2023; Tang et al., 2022).

In light of these opportunities and challenges, there is a clear need to evaluate the holistic impact of EV diffusion on Malaysia's economy and environment. This study projects the effects of widespread adoption of EVs on key economic indicators such as gross domestic product (GDP) and employment, as well as environmental outcomes like CO_2 emissions, in Malaysia. To achieve this, the study employs an environmentally extended input-output (EEIO) model to simulate the economy-wide impacts of the EV transition under different scenarios, including adoption rates of 30%, 50%, and 80%. This approach models shocks like reduced petroleum demand and increased electricity and EV manufacturing demand by capturing inter-industry linkages. The findings will inform Malaysia's EV ambitions' alignment with sustainable development goals and climate commitments, and complementary policies needed for a positive outcome.

This paper is structured as follows: Section 2 reviews relevant literature on electric vehicle diffusion. Section 3 describes the methodology, including input-output modeling, data sources, and scenario design. Section 4 presents simulation results and analyzes economic and environmental impacts. Section 5 discusses policy recommendations for electric vehicle sustainability. Key takeaways, study limitations, and future research directions are concluded.

2. LITERATURE REVIEW

The shift to EVs has significant implications for economic growth, jobs, and the environment. This review organises the discussion into key areas: Macroeconomics, employment, environment, and policy, to analyse EV impacts clearly. Most research focuses on specific sectors rather than broad effects. The following section critically examines these themes, noting the benefits and challenges of the EV transition.

2.1. Economic and Employment Effects

The transition toward EVs presents significant economic opportunities, particularly in renewable energy integration and developing a domestic green manufacturing base. Černý et al. (2022) elucidate that the renewable energy transition creates job opportunities in infrastructure development, maintenance, and the broader economic ecosystem necessary for a sustainable energy framework, potentially mitigating losses from traditional automotive sectors. Agaton et al. (2020) and Bravo et al. (2024) emphasise that investments in EV infrastructure and servicing can generate numerous jobs, notably in charging station installations and battery recycling systems, which are crucial for supporting a sustainable EV market. Furthermore, Tamba et al. (2022) suggest that electrification can have a multiplier effect on employment through increased domestic production capabilities and reduced reliance on imported fossil fuels, benefiting local economies in Europe.

Beyond direct employment shifts, the broader implications of EV diffusion involve significant structural changes related to market adaptations and policy responses. Jia et al. (2023) highlight the importance of strategic planning in managing this transition, indicating that accurate forecasting of EV adoption can influence investments in necessary supporting infrastructure, fostering a positive employment landscape. Policies aimed at facilitating workforce retraining programs for traditional automotive workers transitioning into the EV economy are also critical in alleviating potential unemployment (Koniak et al., 2024).

While there is a consensus on several benefits associated with EVs, there are also significant concerns concerning labour market shifts and environmental implications that prompt contrasting viewpoints in the literature. Weng et al. (2024) present the narrative that manufacturing battery electric vehicles (BEVs) may require fewer workers compared to ICEVs, potentially leading to job losses in the traditional auto vehicle assembly sector. They discuss the claim that the transition to BEVs could reduce the workforce needed for manufacturing by approximately 30%. This sentiment is echoed in works that explore how automation and a shift towards manufacturing processes with fewer moving parts may lead to substantial reductions in the existing workforce (Koniak et al., 2024). Critics argue that such job losses could disproportionately affect regions reliant on traditional manufacturing jobs, exacerbating economic disparities between urban and rural areas.

Moreover, the economic viability of EVs is closely tied to infrastructure development, particularly the rollout of charging stations. Zheng et al. (2024) report that installing EV charging stations (EVCS) significantly boosts nearby businesses' annual spending, suggesting that infrastructure investments can drive local economic growth as EVs become more prevalent. However, complementary infrastructure investments may encounter fiscal constraints or market resistance, hindering widespread adoption and economic benefits (Abas and Tan, 2024).

Bravo et al. (2024) present concerns regarding the potential adverse effects on macroeconomic indicators due to increased reliance on imports for critical components and declines in revenue from fossil fuel exports, particularly from countries reliant on fossil fuel exports. Moreover, Chen et al. (2022) and Sathiyan et al. (2022) argue that achieving carbon neutrality in the automotive sector requires integrating EVs with broader decarbonisation efforts, which include behavioural shifts and technological advancements. This comprehensive outlook supports the idea that while transitioning to EVs presents challenges, the long-term environmental and health benefits, coupled with innovative policy measures, can foster positive economic dynamics.

2.2. Environmental Trade-Offs

One of the primary impacts of EV diffusion is its potential to improve air quality and reduce GHG emissions. Studies indicate that the transition to EVs can significantly lower GHG emissions, enhance air quality, and reduce reliance on fossil fuels, thus enabling a shift towards renewable energy and sustainable transportation systems. For example, Bistline et al. (2022) emphasise that adopting electric technologies lowers CO_2 levels and significantly benefits air quality. Such findings underscore the health and environmental incentives driving the push for EVs. Tamba et al. (2022) reinforce this notion by modelling the impacts of electrification in Europe, predicting substantial reductions in GHG emissions in road transport. The authors argue that widespread EV adoption facilitated by favourable policies can contribute to achieving climate goals, especially in urban areas where air pollution is a pressing concern.

Studies focusing on life cycle assessments (LCAs) of EVs versus ICE vehicles present contradictory viewpoints. Kurkin et al. (2024) acknowledge that although EVs generally have a lower negative impact on the environment over their lifespan, their environmental benefits are significantly affected by the electricity generation mix. For example, Tang et al. (2022) highlight that in regions with high reliance on fossil fuels for electricity generation, EVs may not present considerable environmental advantages over traditional vehicles, particularly regarding GHG emissions. This is notably the case in areas where renewable energy sources are insufficient to support the increasing electricity demand spurred by EV charging.

On the other hand, some studies present a more favourable view of EV. Wang and Tang (2022) suggest that the life cycle carbon emissions of EVs are lower than those of ICE vehicles when accounting for advancements in battery technology and increasing renewable energy penetration in the electricity grid. They discuss the need for a balanced electricity generation approach to enhance the eco-efficiency of EVs. Additionally, Shafique et al. (2022) caution against over-reliance on EVs in regions with low renewable energy adoption, contending that EVs may not be the optimal choice if the energy mix remains heavily fossil-fuel dependent.

Therefore, a crucial element in maximising the environmental benefits of EVs is the source of electricity used for charging. However, Leard and Greene (2023) theorise that substantial GHG reductions can be achieved through EV adoption even if the electricity grid is not immediately decarbonised, highlighting that the geographic focus of EV sales, such as in California, where emissions are already lower, can still provide a beneficial impact on overall CO_2 emissions.

3. METHODOLOGY

Given the complex economic and environmental effects of EV transition, a single-region, demand-driven EEIO model is suitable for this study. The literature highlights EV diffusion impacts on employment, infrastructure, and environmental aspects, but empirical assessments are often sector-specific or lack systemic integration (Bravo et al., 2024; Černý et al., 2022; Kurkin et al., 2024). The EEIO model captures direct and indirect industry linkages, enabling a holistic assessment of how EV-related demand shifts impact GDP, employment, and CO_2 emissions. This comprehensive approach is vital for policy planning in developing countries like Malaysia, where sectoral interdependencies and fiscal trade-offs are crucial.

In this EEIO analysis, input coefficients are based on Malaysia's 2019 I-O tables, adjusted to include a synthetic EV manufacturing sector using international benchmarks. Two policy scenarios model shifts in energy consumption and production, calibrated with national targets and cost benchmarks. The model assumes fixed coefficients, constant prices, and no trade leakages—simplifying but limiting analysis, especially in capturing dynamic, behavioural, or international responses. Results are comparative-static scenarios, not forecasts.

This study uses a static EEIO framework instead of dynamic models like CGE, chosen for its transparency in showing inter-industry linkages key to understanding EV transition shifts. It employs a deterministic interval analysis with bounds from empirical standard deviations to project plausible outcomes amid parameter uncertainty. While it can't simulate behavioural or technological changes endogenously, it offers a clear first-order approximation of sectoral shifts under EV adoption, providing valuable insights without needing the extensive data for dynamic modelling.

3.1. EEIO Model Structure

The I-O framework models the economy as linear equations, with each sector's output allocated to intermediate consumption, final demand, household consumption, government spending, investment, or exports. (Miller and Blair, 2009). The I-O Table is created for a particular base year, based on the System of National Accounts and the Supply-Use Table. (Beutel, 2017). In this table, rows represent the distribution of sectoral output to other industries as intermediate inputs (matrix Z) and to final demand categories (matrix f). Columns, crucial for supply chain analysis, reflect the sourcing of intermediate goods from other sectors (matrix Z) and include primary inputs, such as imported inputs (m), indirect taxes (t), and value-added components (v).

The equation expresses the interdependence among production activities:

$$X = Zi+(c+g+s+e) = Zi+f \tag{1}$$

Where x is the vector for gross output, *Zi* is the sum vector for intermediate demands, and f is the vector for domestic final demands, including household consumption (c), public consumption (g), investment (s), and net exports (e).

This equation can be transformed into a matrix form:

$$X = Ax + f = (I-A)^{-1}f \tag{2}$$

where X is the total output, I is the identity matrix, and A is the I-O coefficient matrix; $L = (I-A)^{-1}$ is the Leontief inverse or input inverse matrix, and f represents the final demand. The Leontief inverse matrix represents the complete demand for producing one unit of final product for each sector's total output.

These equations, structured in matrix form (Equation 1-2), allow for the estimation of key economic indicators, such as output multipliers, which estimate the total output change across all sectors following a change in final demand in a single sector. When environmental extensions are incorporated, specifically CO_2 emissions in this case, the framework enables a simultaneous evaluation of economic and environmental outcomes arising from demand shocks.

This matrix indicates the total production required by each sector to meet its final demand. Each element in this matrix reflects the change in output required by sector i to satisfy a one-unit increase in final demand from sector j. This chapter's I-O methodologies provide a framework for assessing the economic impacts of introducing a new EV industry. Miller and Blair (2009) describe two impact analysis methods: (i) The final demand approach and (ii) adding a new industry to the I-O matrix. This study uses both by modelling shocks on final demand and creating a new EV Manufacturing industry. This allows assessment of the economic and socio-economic effects of demand shocks and new industry creation.

3.1.1. Measuring the economic impacts

This study utilises the gross domestic product (GDP) to measure the economic impact. GDP is the total value of all final goods and services produced by permanent resident units in a country over a specific time frame. It serves as a critical indicator for assessing a country's economic condition (Nourelfath et al., 2022; Sun et al., 2022; Zhang et al., 2025). This analysis uses the income approach for GDP, showcasing production activities for the period based on income generated by resident units, representing the total economic value added across industries. Equations 3-5 illustrate how to calculate each sector's economic impact.

$$m_j = v_j/X_j \tag{3}$$

$$\Delta D = diag(m_j)^*\Delta Y \tag{4}$$

$$\Delta T = diag(m_j)^*L^*\Delta Y \tag{5}$$

Where m_j (j = 1,2,…,n) denotes the value-added coefficient of the sector j, v_j is the total value added of the sector j, and X_j is the total input of the sector j. ΔY is the change in final demand. ΔD and ΔT are the direct and total effects of changes in the unit final demand on economic value-added.

3.1.2. Measuring employment and environmental impacts

Extensions of the Input-Output (I-O) framework allow the evaluation of both direct and indirect effects of economic policies on various factors such as labour, capital, energy, and emissions. Analysing most of these policies requires the use of macroeconomic models that provide detailed industry and product breakdowns (Beutel, 2017).

This study employs this extension to estimate the impact of changes in final demand on employment and the environment. For employment, data from Malaysia's Labour Statistics were used as a vector extension for the analysis. The study utilised data on CO_2 emissions from Malaysia's Fourth Biennial Update Report (UNBUR4) Under the United Nations Framework Convention on Climate Change report for the environment vector (UNFCCC, 2022). The following equation extends the I-O system and applies to multiple analysis approaches.

$$Z = D\left(I - A\right)^{-1}\hat{Y} \tag{6}$$

D = matrix of input coefficients (employment, CO_2 emissions)
$\hat{Y}$ = diagonal matrix for final use
Z = matrix with results for direct and indirect requirements for specific variables in economic analysis (intermediate consumption, labour, capital, energy, etc.)

3.1.3. Multiplier impacts

In I-O analysis, the results from multiplier and linkage analyses help understand a sector's economic impact. Typically, final use categories are exogenous in the I-O model. An output multiplier for industry j is the total production value needed across all industries to produce one unit of product j for final use. If the inverse matrix elements $(I–A)^{-1}$ are used, the output multiplier is:

$$O_j = \Sigma_{i=1}^{n} a_{ij} \tag{7}$$

This multiplier includes both direct impacts from increased demand and indirect impacts on related sectors. In input-output (I-O) analysis, an industry's production affects others directly and indirectly. Backwards linkages connect to input-providing industries, while forward linkages relate to industries using outputs as inputs. The Leontief model detects backwards linkages, and the Ghosh model detects forwards linkages, with their extent calculated using respective inverse matrices.

If l_{ij} is the $n \times n$ matrix of the Leontief inverse $(I–A)^{-1}$ then, the backwards linkage B_{Lj} of the sector is computed as:

$$BL_j = \sum\nolimits_{i=1}^{n} l_{ij} \tag{8}$$

If g_{ij} is the $n \times n$ matrix of the Ghosh inverse $(I–B)^{-1}$ then, the forward linkage FL_j of the sector i is computed as:

$$FL_j = \sum\nolimits_{j=1}^{n} g_{ij} \tag{9}$$

3.1.4. Data sources and sectoral modifications

To enhance the accuracy and relevance of this study, a modified Input-Output (I-O) table will be derived from the 2019 Malaysia National I-O Table published by the Department of Statistics Malaysia (DOSM). The official I-O table was reviewed, refined, and reconstructed to accommodate the specific details of the EV industry. A comprehensive understanding of the Malaysian economy and the relevant industries involved in EV production and their linkages is critical for this stage.

The I-O table will then be aggregated into 39 sectors, highlighting Malaysia's key industries as shown in Appendix 1. This aggregation ensures a more accurate reflection of the technologies and inputs used in the EV industry and its interconnections with other economic sectors (Cabrer et al., 1991). The aggregation utilised the data from the Social Accounting Matrix published by the Malaysian statistical department, enhanced with the newly constructed EV manufacturing industry for this study.

The aggregated table serves as the foundation for this analysis, offering insights into interrelationships between various sectors. As EV manufacturing is not yet established in Malaysia, the study by Zhao et al. and M. Rocco et al. provides a reference for creating the new EV manufacturing sector (Rocco et al., 2018; Zhang et al., 2025; Zhao et al., 2022). The existing vehicle manufacturing sector will be disaggregated to create a new EV subsector. The industry structure will adopt Zhang et al. (2025) and be modified to adjust to the Malaysian environment. Then, the RAS procedure was applied to rebalance the table (Junius and Oosterhaven, 2003). Once the table is transformed into an aggregated and balanced I-O model, various scenarios incorporating the introduced shocks are applied to compare the modified model with the baseline.

3.2. Scenario Development and Assumptions

This study presents two scenarios to evaluate how EV adoption might reshape Malaysia's economy and environment. Scenario 1 looks at changes in energy demand from replacing ICE vehicles with EVs, focusing on the petroleum and electricity sectors. Scenario 2 considers the shift in automotive manufacturing from ICE vehicles to EVs. These scenarios capture both demand and supply changes, providing a comprehensive view of structural impacts aligned with Malaysia's decarbonisation goals.

3.2.1. Scenario 1-The shift from consumers relying on petroleum to power their vehicles to utilising electricity

This shift will affect the petroleum refining industry due to diminishing demand for petroleum. However, as the I-O analysis is based on a fixed coefficient assumption, it will only show the impact on local production. The shock for this scenario can be represented in two parts. The first is a reduction in the demand for petroleum as the number of ICE vehicles declines. This first shock can be represented as:

$$S_{1.1} = -1 \cdot P_t \cdot V_{2019} \cdot C_{ICE} \cdot Price_{per\ litre} \tag{10}$$

The second part of the scenario can be represented as:

$$S_{1.2} = P_t \cdot V_{2019} \cdot C_{EV} \cdot Price_{per\ kW} \tag{11}$$

P: The projected EV share for the year t.
V: Total number of vehicles for the base year 2019.
C_{ice}: Average annual petroleum consumption (litres)
C_{ev}: Average annual electricity consumption (kW)

The variables in equations (10) and (11) are defined as follows: S1.1 denotes the estimated shock in petroleum demand, while S1.2 signifies the electricity demand. A negative value (−1) is employed in S1.1 to indicate the negative shock due to reduced demand. The projected EV share (P) was estimated to be 30%

in 2030, 50% in 2040, and 80% in 2050. The total number of vehicles used is a static value, reflecting the number of vehicles in the base year of the I-O table (2019), which is 14.7 million four-wheeled light-duty vehicles, constituting 47% of total vehicles on the road (Figure 2).

The sectoral compositions of the petroleum refining and electricity generation industries, which form the baseline for Scenario 1, are detailed in Appendix 2. The average petroleum and electricity consumption was estimated using readily published data on various ICE vehicles and EVS available in the Malaysian market. For ICE vehicles, the collected data indicates that average vehicles travel 19.1 km for each litre of petroleum consumed (std dev.: 1.879), whereas for EVs, the average vehicles travel 6.4 km for every kW used (std. dev.: 0.986). Drawing on earlier research regarding the average kilometres travelled by private vehicles in Malaysia, the analysis posited that the annual average kilometres travelled by these vehicles stands at 24,129 km (std dev.: 3,000.7 km) (Shabadin et al., 2014).

In Malaysia, the price of petrol is regulated. The regulated price for 2019 fluctuated between RM2.20 and RM1.92, with an average price of RM2.07. The cost of electricity for EV charging is calculated based on the assumption that average EV users charge their vehicles 50% at home (RM0.571/kW) and 50% at commercial charging stations (RM1.50/kW), resulting in an overall cost of RM1.035/kW.

3.2.2. Scenario 2-The shift from traditional ICE vehicle manufacturing to EV manufacturing

The study assumes Malaysian vehicle manufacturers will allocate some production to EVS due to the significant initial capital needed for EV startups. It evaluates the economic impact of declining ICE vehicle production as the industry shifts to Evs, considering EV manufacturing as a separate sector. The impact of reduced ICE manufacturing is expressed as:

$$S_{2.1} = -1 \times P_t \times Q_{2019} \times L_{ICE} \quad (12)$$

The EV manufacturing sector then produces the reduced production from the traditional motor vehicles industry. The shock can be expressed as:

$$S_{2.2} = P_t \times Q_{2019} \times L_{EV} \quad (13)$$

The variables in equations (12) and (13) are defined as follows: S2.1 represents the estimated shock in traditional vehicle manufacturing, and $S_{2.1}$ represents the estimated shock in EV manufacturing. Similar to Scenario 1, P_t denotes the projected EV market share in the years 2030, 2040 and 2050. Q_{2019} refers to the total number of vehicles produced by the domestic industry in the base year 2019 (Figure 3), and L_{ICE} is the average price for a unit of a conventional ICE car, while LEV is the average price for a unit of an EV car. The average cost of an ICE vehicle is determined by collecting data on Malaysia's most fuel-efficient cars priced under RM100,000. The average price for a sample of 16 is RM66,373, with a standard deviation of RM24,444.9. For reference, the top three most popular mid-range models produced in Malaysia are the Perodua Alza (RM62,525), Perodua Ativa (RM62,500), and Proton X50 (RM86,300).

Figure 2: Motor vehicle registration malaysia for selected years. (UNFCCC, 2022)

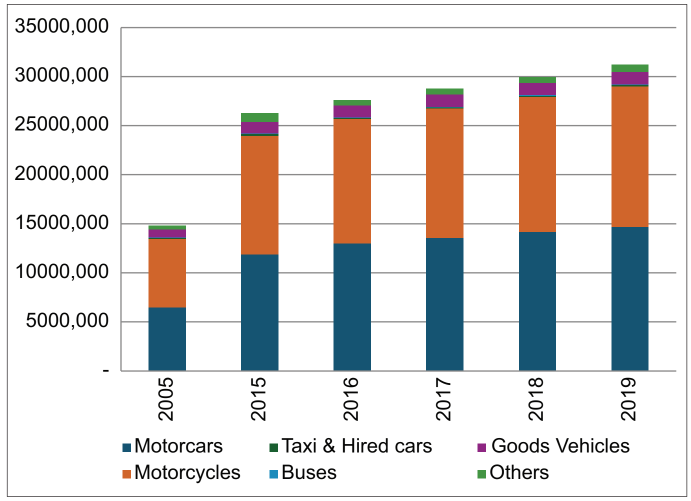
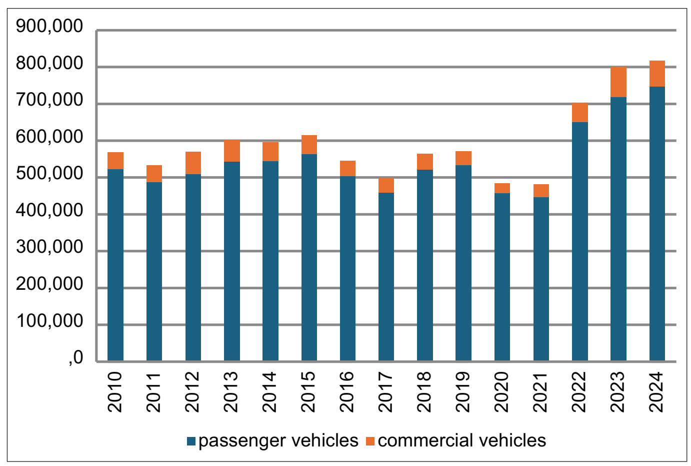


Figure 3: Motor vehicle production in Malaysia, 2010-2024. (Malaysian Automotive Association, 2025)



EVs exhibit significant variance, with European models often being priced considerably higher than those from China. Meanwhile, Malaysia has introduced a national EV, the Proton e-Mas 7, which is positioned in a lower price range. For this simulation, the average price of an EV is calculated based on the three cheapest models in Malaysia currently: Neta V (RM100,000), Proton e-Mas 7 (RM124,000), and Ora Good Cat (RM134,000).

3.3. Uncertainty and Sensitivity Analysis

This study uses an interval range approach to manage uncertainties due to the I-O method's limitations, which lack probabilistic data. Interval analysis computes with ranges, providing guaranteed bounds despite input uncertainties (Moore et al., 2009). For uncertain parameters like kilometres travelled or annual fuel consumption, plausible lower and upper bounds are set using standard deviations. Assuming normal distribution, about 95% of observations fall within two standard deviations of the mean. (Lind et al., 2005). The I-O model is then solved for these extreme values, resulting in a range of possible outcomes. This creates a worst-case versus best-case envelope. Interval analysis is especially useful for managing structural uncertainties that are not easily captured as statistical distributions.

Additionally, this study includes sensitivity analysis for various EV adoption scenarios, estimating for 30%, 50%, and 80% EV shares of the total transportation, aligning with Malaysia's NETR target of reaching 80% EV share by 2050.

3.4. Model Assumptions

The study uses a demand-driven EEIO model with key assumptions. It assumes fixed technical coefficients, proportionality in output changes with demand, and conducts analysis at constant prices without considering price effects like inflation or input substitution. Domestic production meets EV demand proportionally without modelling trade leakages or capacity limits. Employment effects are estimated with constant ratios, assuming stable productivity. Sectoral CO_2 emissions are calculated linearly without efficiency improvements. EV adoption scenarios (30%, 50%, 80%) are exogenous, ignoring behavioural feedback and policy changes, but align with Malaysia's national goals for decarbonisation and EV adoption outlined in NETR, NAP, and LCMB 2021-2023, supporting strategic planning toward carbon neutrality by 2050.

While the model simplifies assumptions, it offers a transparent, manageable framework to assess EV diffusion's broad economic and environmental effects. Given data limitations and the need for practical insights in Malaysia, the EEIO approach is a useful starting point for policy and investment decisions despite its constraints. Its main limitation is the static nature, with fixed technical coefficients that ignore factors like technological progress, input substitution, or economies of scale in the emerging EV sector. It also doesn't explicitly account for dynamic impacts of government incentives or market responses to policies fostering EV adoption and local production. Hence, results should be seen as comparative-static scenarios based on the 2019 economic structure, not future forecasts. Future research should explore CGE or dynamic IO models for more detailed policy analysis.

4. RESULTS AND DISCUSSION

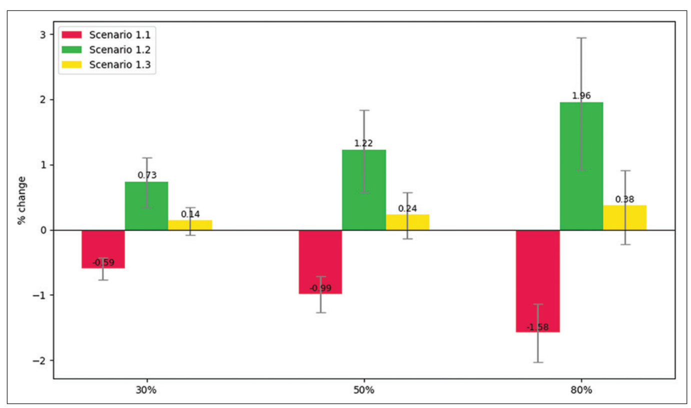
This section presents the findings and discussions of Scenario 1 and Scenario 2, along with the multiplier analysis The goal is to examine the impacts, compare outcomes, and understand broader effects through the multiplier analysis. This approach offers a comprehensive view, facilitates discussions, and informs policy recommendations in the next section.

4.1. Macroeconomic Impacts

Both EV scenarios reveal a complex mix of economic gains and losses, with simulations indicating net GDP growth for each (Scenarios 1.3 and 2.3). The simulated impacts on Malaysia's GDP under both EV transition scenarios are summarized in Table 1, with specific lower and upper bounds provided for each adoption target. Without growth compensation from electricity, reduced petroleum activity would impose significant costs. A decline in petroleum demand (Scenario 1.1) is expected to reduce Malaysia's GDP by 1.58% with an 80% EV share, while a decrease in ICE vehicle manufacturing (Scenario 2.1) leads to a 1.32% GDP drop at the same EV share. These losses underscore Malaysia's heavy dependence on petroleum refining and the ICE vehicle industries, highlighting the risks of a disruptive transition if not managed carefully. Previous studies warn that abrupt declines in fossil fuel industries can hinder growth in dependent economies (Bistline et al., 2022; Tamba et al., 2022; Weng et al., 2024).

Encouragingly, when the expansion of alternative sectors is taken into account, the negative effects are outweighed by new growth. The increase in electricity-related activity from EV charging demand (Scenario 1.2) is expected to make a positive contribution to GDP, ultimately surpassing the losses in the petroleum sector and yielding a modest net GDP increase of 0.38% at an 80% EV share (Figure 4). Similarly, boosting EV manufacturing (Scenario 2.2) significantly enhances economic output, projecting a 2.10% increase in GDP at the same EV share, which more than compensates for the decline of ICE manufacturing, as illustrated in Figure 5. Therefore, the overall net effect in Scenario 2 becomes positive, growing to 0.79% at the maximum EV share. The Malaysian economy thus

Figure 4: Simulation results on GDP for scenario 1 at 30%, 50% and 80% EV share



Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net effect of scenarios 1.1 and 1.2

Table 1: GDP results for scenarios 1 and 2 with lower and upper bounds in brackets (% change)

EV share (%)	Scenario 1			Scenario 2		
	1.1	1.2	1.3	2.1	2.2	2.3
30	−0.59 (−0.76-−0.43]	0.73 (0.35-1.10)	0.14 (−0.08-0.34)	−0.49 (−0.68-−0.31)	0.79 (0.64-0.85)	0.30 (0.18-0.32)
50	−0.99 (−1.27-−0.71)	1.22 (0.58-1.84)	0.24 (−0.14-0.57)	−0.82 (−1.13-−0.52)	1.32 (1.06-1.42)	0.49 (0.30-0.54)
80	−1.58 (−2.03-−1.14)	1.96 (0.92-2.94)	0.38 (−0.22-0.91)	−1.32 (−1.80-−0.83)	2.10 (1.70-2.27)	0.79 (0.47-0.87)

Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net effect of scenarios 1.1 and 1.2. Scenario 2.1 refers to a decrease in demand for ICE Vehicles; scenario 2.2 refers to an increase in demand for EVs; scenario 2.3 refers to the net effect of scenarios 2.1 and 2.2

stands to gain in aggregate from EV diffusion, provided growth in the new industry can sufficiently counterbalance the declines in legacy sectors. These findings resonate with the conclusions of several studies that observed that EV diffusion can stimulate net economic growth (Agaton et al., 2020; Bravo et al., 2024).

The magnitude of economic impacts differ between the two transition strategies. The fuel-to-electricity transition (Scenario 1) is projected to result in a minimal GDP increase in the near term (0.14% at 30% EV share), as Malaysia's power sector growth offsets oil-related losses. Over time, as electricity sector investments mature, the GDP benefit slightly grows (reaching 0.38% at 80% EV share). The modest GDP gains from the fuel-to-electricity transition are a function of the specific sectoral multipliers for these energy industries (see Appendix 2). In contrast, the shift to an EV-manufacturing economy (Scenario 2) shows a considerable and accelerating long-term GDP gain. Initially, net effects are limited due to required upfront capital investments and underdeveloped local EV supply chains. When EV share reaches 80%, however, the expanding EV industry is estimated to lead to a significant GDP rise (net 0.79%), indicating that this new manufacturing sector has the potential to compensate for lost output and drive further growth as it achieves economies of scale.

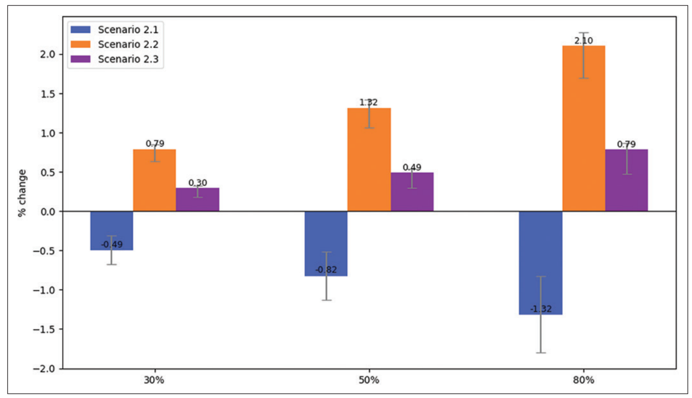
Several factors explain Scenario 2's greater economic impact. The greater economic impact of Scenario 2 is driven by its high-value, technology-intensive nature and its deep linkages with sectors like electronics and chemical products, as evidenced by the sectoral contribution rankings in Appendix 3. EV manufacturing is a high-value, technology-intensive sector producing electric cars and components like battery packs, power electronics, and software integration. These activities generate premium value and spillover benefits in the electronics industry and advanced materials. This study's I-O analysis shows that Malaysia's motor vehicle industry, pivoted to EVs, relies on a diversified supply chain (e.g., electronics, metals, chemicals) instead of just traditional inputs. This diversification boosts resilience and local value capture, enhancing the EV sector's GDP contribution.

In contrast, the electricity sector's growth in Scenario 1 is limited by its capital intensity and dependence on fossil fuels (e.g., coal and gas), resulting in modest gains. However, growth in both scenarios indicates that EV diffusion can stimulate Malaysia's economy with the proper support. This is consistent with Malaysia's NAP and LCMB, which prioritise EV industry development, technological advancement, and localisation of EV components. These efforts are further reinforced by the NETR, which outlines targets for EV uptake and renewable energy integration. These policies underscore a strategic national commitment to a green industrial shift, aligning closely with this study's findings. Similar to previous research, this analysis shows that investments in clean energy infrastructure, like power grid upgrades, can create significant economic value over time (Agaton et al., 2020; Koniak et al., 2024).

4.2. Employment Impact

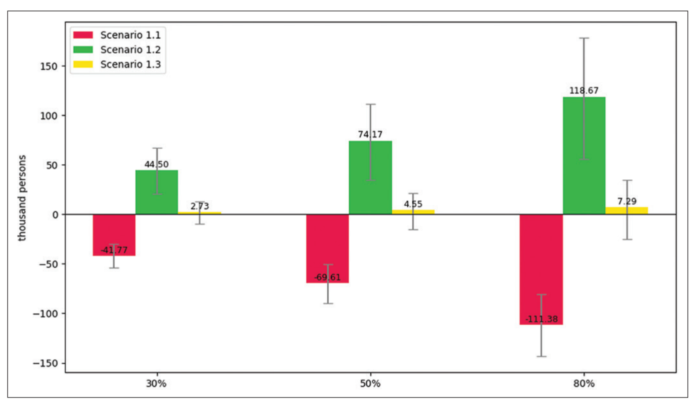
The transition to electric mobility significantly impacts the labour market, shifting job composition without clear net gains. As detailed in Table 2, the transition is projected to generate significant labor shifts, with the net employment effect varying across the 30%, 50%, and 80% EV share targets. In Scenario 1, transitioning from petroleum to electric power is projected to result in a modest net gain of a few thousand jobs (7.29 thousand) at an

Figure 5: Simulation results on GDP for Scenario 2 at 30%, 50% and 80% EV share



Scenario 2.1 refers to a decrease in demand for ICE vehicles; scenario 2.2 refers to an increase in demand for EVs; scenario 1.3 refers to the net impact of scenarios 2.1 and 2.2

Figure 6: Simulation results on employment for Scenario 1 at 30%, 50% and 80% EV share



Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net impact of scenarios 1.1 and 1.2

Table 2: Employment results for scenario 1 and 2 with lower and upper bounds in brackets (thousand persons)

EV share	Scenario 1			Scenario 2		
(%)	1.1	1.2	1.3	2.1	2.2	2.3
30	−41.8 (−53.8-−30.2)	44.5 (20.9-66.8)	2.7 (−9.3-13.0)	−55.7 (−76.2-−35.1)	98.9 (79.8-106.9)	43.26 (30.7-44.7)
50	−69.6 (−89.7-−50.3)	74.2 (34.9-111.4)	4.6 (−15.5-21.7)	−92.8 (−127.0-−58.6)	164.9 (133.0-178.2)	72.1 (51.2-74.4)
80	−111.4 (−143.6-−80.5)	118.7 (55.8-178.2)	7.3 (−24.8-34.7)	−148.5 (−203.3-−93.7)	263.8 (212.8-285.1)	115.4 (81.9-119.1)

Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net effect of scenarios 1.1 and 1.2. Scenario 2.1 refers to a decrease in demand for ICE Vehicles; scenario 2.2 refers to an increase in demand for EVs; scenario 2.3 refers to the net effect of scenarios 2.1 and 2.2

80% EV share (see Figure 6). Scenario 2 shows a larger effect, with switching from ICE to EV manufacturing potentially adding 115,000 new jobs in the same scenario. While these figures suggest that job creation in emerging EV-related sectors can outweigh losses in declining industries, the transition also entails substantial workforce displacement and reskilling challenges, particularly in petroleum refining and traditional automotive manufacturing.

In scenario 1, phasing down the petroleum fuel industry is estimated to result in a loss of around 111,000 jobs across oil refining, fuel distribution, and related supply chains at maximum EV penetration. These losses will disproportionately impact regions and workers reliant on fossil fuel-related activities. However, the corresponding growth in electricity demand due to EV charging is expected to generate nearly 119,000 new jobs in the electricity sector and its associated infrastructure. These roles concentrated in grid construction, power generation, EV charging installation, and energy system maintenance align with Malaysia's broader push for energy transition and industrial modernisation.

Scenario 1 shows a slightly positive net effect, potentially gaining 2.7-7.3 thousand jobs from 30% to 80% EV share, nearing break-even. This highlights that while the electricity sector grows, it is less labour-intensive than the petroleum sector it replaces, absorbing just enough workers to offset displacements. The uncertainty analysis indicates a risk of negative net employment gains, dependent on new project implementation efficiency, ranging from about −24.8 thousand to 34.7 thousand at the maximum EV share scenario. The petroleum-to-electric transition alone will not guarantee job growth; it needs careful management to help workers from declining industries fill new roles.

These finding have direct policy implications and support several national aspirations outlined the NETR, LCMB and NAP 2020. For instance, the LCMB emphasises not only EV deployment but also the promotion of supporting services, infrastructure, and capacity-building initiatives. Similarly, NETR aims to ensure a "just energy transition" which includes creating high-quality green jobs and supporting vulnerable workers in legacy sectors. The large scale employment shift projected in this study reinforces the urgency of these policy priorities.

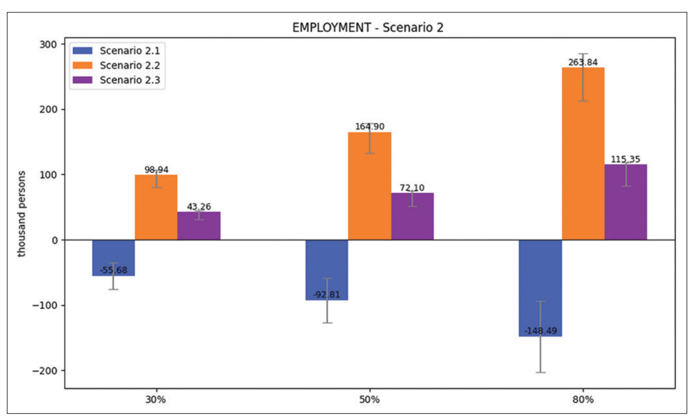
To bridge the gap between job losses in fossil fuel sectors and emerging opportunities in the EV economy, policy measures should prioritise reskilling and upskilling initiatives. Targeted programs such as vocational retraining in battery technology, electrical systems, and EV maintenance can enable displaced workers to transition into clean energy roles. Previous research has shown that such transitions often stimulate technical and service-based employment, particularly in renewable energy infrastructure and clean technology deployment (Borgstedt et al., 2017; Ram et al., 2020). Integrating these initiatives in Technical and Vocational Education and Training (TVET) programs as emphasised in the 12th Malaysia Plan, can help ensure long-term workforce readiness. Furthermore, regional employment strategies should be developed to address spatial inequalities arising from industry shifts, particularly in areas heavily dependent on fossil fuel infrastructure. By aligning workforce development with Malaysia's EV and green energy policies, the country can maximise employment gains while supporting a socially inclusive transition. These efforts will be critical in turning the EV revolution into a sustainable and equitable economic transformation.

Scenario 2 features significant labour reallocation due to Malaysia's large automobile industry. A decline in ICE vehicle production risks many manufacturing and supplier jobs. Simulation results for Scenario 2.1 indicate job losses in the conventional auto industry and supply chain could exceed 90,000 at an 80% EV share. These losses affect assembly line workers, parts manufacturing employees (engines, transmissions, exhaust systems), and services related to ICE vehicles. This contraction stems from the high labour intensity of traditional automotive manufacturing, which relies on a large, semi-skilled workforce in Malaysia, affecting parts suppliers and dealerships.

Establishing and growing the EV manufacturing sector (Scenario 2.2) is expected to create about 264,000 jobs (at 80% EV share) in battery production, electric drivetrain components, electronics, and vehicle assembly. This results in a significant positive employment impact. Figure 7 presents the larger effect observed in Scenario 2, where switching to EV manufacturing potentially adds 115,000 new jobs. These figures indicate that, with suitable conditions, the emerging EV industry can absorb workers displaced from ICE manufacturing. This finding is supported by Fragkiadakis et al. (2020), who suggest that while EV adoption may reduce jobs in traditional engine production, it also creates new employment opportunities in battery manufacturing, power electronics, and EV maintenance. The Malaysian case supports this view, but it is crucial to recognise that the new jobs do not directly replace the old ones.

A fundamental challenge lies in the changing nature of work. EV production is more automated and capital-intensive than traditional vehicle manufacturing, particularly in battery and electronics assembly. Consequently, many new manufacturing jobs require higher technical skills or advanced engineering knowledge, while the number of assembly-line workers per vehicle decreases (Weng et al., 2024). The simulation result highlights structural shifts.

Figure 7: Simulation results on employment for Scenario 2 at 30%, 50% and 80% EV share



Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net impact of scenarios 1.1 and 1.2

Table 3: CO_2 results for scenarios 1 and 2 with lower and upper bounds in brackets (Gg CO_2 equivalent)

EV share	Scenario 1			Scenario 2		
(%)	1.1	1.2	1.3	2.1	2.2	2.3
30	−3725.8 (−4801.7-−2694.1)	3596.0 (1689.6-5401.3)	−129.8 (−1004.5-599.7)	−2542.2 (−3479.9-−1604.5)	5253.4 (4236.6-5677.1)	2771.2 (2179.1-2790.3)
50	−6209.7 (−8002.8-−4490.1)	5993.4 (2816.0-9002.2)	−216.3 (−1674.1-999.4)	−4237.0 (−5799.9-−2674.2)	8755.7 (7061.0-9461.8)	4518.6 (3661.9-4650.5)
80	−9935.5 (−12804.5-−7184.2)	9589.4 (4505.6-14403.6)	−346.1 (−2678.6-1599.1)	−6779.3 (−9279.8-−4278.7)	14009.1 (11297.7-15138.9)	7229.8 (5859.0-7440.7)

Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net effect of scenarios 1.1 and 1.2. Scenario 2.1 refers to a decrease in demand for ICE Vehicles; scenario 2.2 refers to an increase in demand for EVs; scenario 2.3 refers to the net effect of scenarios 2.1 and 2.2

While the net employment effect is positive, job composition shifts towards knowledge-intensive roles like battery engineers, electrical technicians, software developers, and chemical specialists, causing a decline in machinery operators and engine mechanics. This presents both opportunities and challenges. The transition can create more high-quality jobs that offer better pay and career advancement in growing technological fields.

These insights underscore the importance of labour policy reforms to support a just transition, as emphasised in Malaysia's NETR and LCMB. Both documents advocate for proactive measures to reskill and upskill the workforce, particularly in sectors undergoing structural disruption. Integrating green skills into TVET curricula and expanding partnerships between government, industry, and educational institutions will be critical. These efforts must also align with the NAP 2020, which encourages localisation of EV supply chains and workforce readiness for next-generation vehicles.

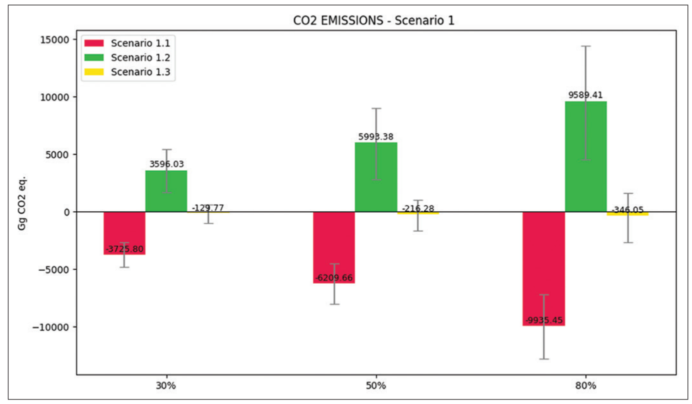
Without such interventions, Malaysia risks facing structural unemployment even as new opportunities arise. The study's results call for a coordinated national strategy that bridges industrial transformation with human capital development, ensuring that the EV transition delivers inclusive economic benefits in line with Malaysia's broader aspirations for green growth and carbon neutrality.

4.3. Environmental Impact

The environmental trade-offs between reduced tailpipe emissions and increased power-sector output are presented in Table 3, highlighting the limited net reduction in GHG emissions under the current electricity mix. Scenario analyses reveal that replacing ICE vehicles with EVS (Scenario 1) results in only a modest net GHG emissions reduction under the current energy mix. Reduced petroleum consumption significantly cuts direct emissions, with avoided emissions from gasoline and diesel projected to reach 9935.45 Gg CO_2-e at 80% EV share (Figure 8). This highlights the major reduction in CO_2 output from fewer combustion-engine vehicles on the road.

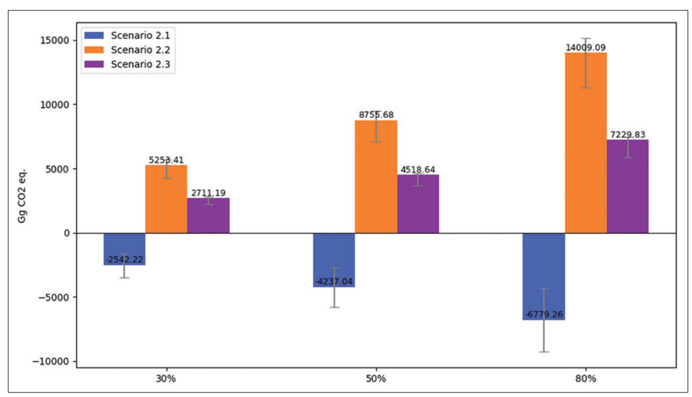
EVs in Malaysia mainly rely on fossil fuel-generated electricity, increasing power-sector emissions by 9589.41 Gg CO_2-e at the maximum EV share scenario (Scenario 1.2). Netting the effects demonstrates a minimal emissions benefit, with a net reduction of only 130 Gg CO_2-e in the lowest EV share scenario, increasing to approximately 346 Gg CO_2-e in the highest EV share scenario. Thus, the electrification of transport has a limited effect on overall CO_2 emissions, as reductions from lower fuel consumption are nearly offset by emissions from generating additional electricity.

Figure 8: Simulation results on CO_2 emissions for Scenario 1 at 30%, 50% and 80% EV share



Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net effect of scenarios 1.1 and 1.2

Figure 9: Simulation results on CO_2 emissions for Scenario 2 at 30%, 50% and 80% EV share



Scenario 2.1 refers to a decrease in demand for ICE vehicles; scenario 2.2 refers to an increase in demand for EVs; scenario 1.3 refers to the net impact of scenarios 2.1 and 2.2

The implication is that, under Malaysia's current electricity generation profile, which is dominated by coal and natural gas, EVs alone are insufficient to address carbon emissions. This finding reinforces a point often made in environmental assessments, which suggests that the benefits of EVs are highly contingent on the cleanliness of the electric grid (Kurkin et al., 2024; Tang et al., 2022). Shifting from petrol to EVs transfers emissions from millions of tailpipes to fewer power plants. If these plants use fossil fuels, the overall greenhouse impact may be negligible, as shown in Scenario 1. Significant reductions in Malaysia's GHG emissions from EV adoption require substantial increases in renewable electricity or other low-carbon power sources, which will be discussed in the policy discussion.

Findings for Scenario 2 show that ramping up domestic EV production in Malaysia could increase net emissions compared to the status quo. In Scenario 2.1, reducing ICE vehicle manufacturing leads to decreased industrial emissions, estimating 6779.26 Gg CO_2-e saved (80% EV share) as traditional car production declines. However, Scenario 2.2 reveals that a robust EV manufacturing sector may offset these savings, with emissions from EV battery and drivetrain production expected to rise by approximately 14,000 Gg CO_2-e (80% EV share). The manufacturing phase of the EV industry is energy- and carbon-intensive, primarily due to battery production, which involves demanding processes and high electricity consumption. In Malaysia, where fossil fuels power much of the industrial electricity, these practices contribute significantly to carbon emissions. Consequently, Scenario 2 leads to a net increase in emissions, adding 2711.19 Gg CO_2-e in 2030, reaching 7229.83 Gg CO_2-e by 2050 compared to the baseline. The projected rise in emissions for Scenario 2 is summarised in Figure 9.

In other words, if Malaysia were to become a regional hub for EV production without greening its energy sources, the country could paradoxically see higher overall emissions despite the proliferation of zero-emission vehicles. This counterintuitive result highlights a crucial insight: The environmental superiority of EVs extends beyond tailpipe emissions to encompass their production and power sources. Other researchers have noted this trade-off; for instance, manufacturing an electric car, especially its battery, can emit significantly more CO_2 than manufacturing a conventional car (Chen et al., 2023; Wang and Tang, 2022; Zheng and Tian, 2021).

The results show that EV expansion must coincide with cleaner power and industrial processes for a positive environmental outcome. An EV revolution is insufficient for reducing emissions; it must align with the renewable energy revolution. This insight has significant policy implications; to fully utilise EVs for climate benefits, Malaysia must accelerate the decarbonisation of its electricity grid and encourage low-carbon manufacturing techniques. Otherwise, the EV transition could slow progress toward the country's CO_2 reduction targets.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study demonstrates that the diffusion of EVs can stimulate Malaysia's economy and generate new employment opportunities. However, the magnitude of these benefits varies by scenario and comes with environmental caveats. The results show only modest gains in a limited electrification scenario where transport shifts from petroleum to electricity, ceteris paribus. When EV adoption reaches 80% of the transport share, GDP will rise by <½%, and roughly 7,000 net jobs will be added. These modest improvements occur because increased activity in the power sector barely outweighs the losses in the petroleum industry.

In contrast, a more transformative scenario in which Malaysia develops a robust EV manufacturing industry yields significantly greater economic benefits. Increasing EV production more than compensates for the reduction in ICE vehicle manufacturing, resulting in net GDP growth and tens of thousands of new jobs. This reflects EV technology's higher value-added nature and supporting industries' growth. Notably, by mid-century, the EV manufacturing expansion scenario could create over 100,000 net new jobs, offering a sizable boost to employment if Malaysia successfully captures this emerging market. However, this study's findings also underscore that environmental benefits are not guaranteed. Without cleaner electricity and industrial practices, the rise in electricity demand and factory output for EVs can offset or even exceed the emissions savings from reduced fossil fuel use. In fact, under current grid conditions, the net CO_2 impact of widespread EV adoption could be negligible or slightly negative, an outcome that would undermine Malaysia's climate goals. These results make clear that EV adoption must be accompanied by concurrent decarbonisation efforts to deliver sustainable development truly.

A coordinated strategy is required to capitalise on the economic opportunities of EVs while safeguarding environmental objectives. Based on the evidence, this study offers the following policy recommendations aimed at both government and private sector stakeholders.

- Support a just transition through workforce reskilling: A proactive labour transition program is essential for workers from declining petroleum and ICE sectors to participate in the EV and clean energy economy. The government should expand retraining initiatives focused on EV-related skills like battery technology, electric drivetrain maintenance, and sustainable manufacturing techniques. These programs can be delivered through technical institutes and partnerships with industry. By equipping displaced oil and automotive workers with skills for EV production and high-tech manufacturing, Malaysia can mitigate job losses and meet the demand for skilled labour. Establishing just transition frameworks with financial support, job placement assistance, and hiring incentives for companies is crucial. The private sector must collaborate on curriculum design and offer apprenticeships or training in new EV factories. This focus on human capital will cushion the social impacts of the transition and ensure a capable workforce for the EV industry's growth.
- Accelerate clean energy expansion for EV integration: Electrifying transport yields environmental gains only if electricity is clean. Thus, energy policymakers must enhance renewable energy generation and modernise the grid alongside rising EV adoption. Malaysia's government should boost policies and investments to increase solar, wind, hydro, and other renewables in the power mix, as outlined in the NETR; implementation is key. Expanding grid capacity and smart grid technology is critical for meeting EV charging demand with green power. The private sector, especially utility companies and independent power producers, should invest in large-scale renewable energy projects. Malaysia can ensure new electric cars contribute to lower carbon emissions rather than merely shifting pollution from tailpipes to power plants. Policies

could also promote green charging initiatives by linking public charging stations to on-site solar panels or offering lower electricity tariffs for EV charging during excess renewable supply. Such measures would align the transport and energy sectors, showing that EV policy is climate policy. In sum, a cleaner grid will enhance the environmental benefits of EVs, improve public health by reducing air pollution, and create new jobs in the renewable energy sector.

- Foster green manufacturing and domestic EV industry development: Harnessing the economic potential of the EV transition requires building a robust domestic EV manufacturing ecosystem. The government should implement industrial policies to attract investment in EV production and the supply chain, positioning Malaysia as a regional hub for green automotive manufacturing. This may include targeted incentives like tax breaks, research grants, and co-financing for companies establishing EV assembly plants, battery gigafactories, or component manufacturing in the country. Malaysia can enhance domestic value-added and technology transfer from the EV boom by developing local supply chains for key EV components, especially batteries, semiconductors, and advanced materials. The study shows that EV manufacturing has high economic multipliers and spillover benefits, necessitating the nurturing of local capabilities in high-tech sectors. The private sector should capitalise on these opportunities by investing in modern, energy-efficient production lines and forming partnerships to acquire cutting-edge knowledge. It is crucial to integrate green manufacturing practices from the start, using cleaner processes and energy sources, such as solar energy for assembly plants, while adhering to international environmental standards to minimise the carbon footprint of EV production. Developing a reputation for sustainably manufactured EVs and components could provide Malaysian products a competitive advantage in global markets increasingly focused on carbon intensity. In summary, Malaysia can achieve significant GDP and employment growth by expanding a green EV manufacturing sector while fostering innovation and ensuring environmentally responsible industrial development.
- Ensure coordinated policy planning between energy and transport sectors: This study highlights that energy and transport policies must integrate to achieve economic growth and emissions reduction. Transportation and energy agencies should follow a unified roadmap through an inter-ministerial task force, aligning EV targets with grid decarbonisation and capacity expansion timelines. Established by the Ministry of International Trade and Industry (MITI) in 2022, the task force leads infrastructure expansion, policy, incentives, public-private collaboration, and education efforts. Coordination among utilities, automakers, public transit agencies, and charging network providers is essential for integrated planning. This holistic approach prevents issues like electricity demand outpacing clean energy supply or slow charger rollout hindering EV adoption. Each transition element can reinforce others, from workforce training to energy investment and urban planning. By breaking silos between energy and transport initiatives, Malaysia can create synergies to enhance the EV transition benefits. An integrated strategy will ensure the vehicle fleet electrifies while supporting infrastructure and energy systems evolve for a smoother transition and maximum benefits for the economy, society, and environment.

In conclusion, the diffusion of EVs in Malaysia presents a promising but complex opportunity. This study's core finding is that while economic and employment outcomes are broadly positive, the environmental benefits of EV adoption are limited or even negative under Malaysia's current fossil-based electricity mix. Without accelerated grid decarbonisation, increased electricity and manufacturing emissions may offset or exceed tailpipe emission reductions. Policymakers and businesses must, therefore, act on multiple fronts. By investing in people, clean power, green industry, and cross-sector coordination, Malaysia can ensure that the EV revolution drives growth and job creation and advances national sustainability goals. Suppose these evidence-based measures are pursued in unison. In that case, the country will be well-positioned to transform the transportation-energy landscape into one that is economically vibrant, socially equitable, and environmentally sustainable for decades.

This study offers insightful perspectives on the economic and environmental effects of EV diffusion in Malaysia while acknowledging certain limitations. The static input-output framework might not capture dynamic economic adjustments like capital reallocation, innovation, or industry shifts. It also omits behavioural responses, policy feedback, and broader environmental issues such as battery waste, land use, and rare earth mineral costs. The analysis relies on predefined EV adoption scenarios, which could be affected by financial, regulatory, or infrastructural factors. International trade effects, like import dependency and supply chain issues, are not included. The data, from 2019, may not reflect recent technological advances. These points suggest future research could benefit from more dynamic models, like dynamic I-O analysis or CGE. Future studies may benefit from exploring alternative methodologies and data to provide a more rounded view of the industry's evolution.

REFERENCES

Abas, P.E., Tan, B. (2024), Modeling the impact of different policies on electric vehicle adoption: An investigative study. World Electric Vehicle Journal, 15(2), 052.

Agaton, C.B., Collera, A.A., Guno, C.S. (2020), Socio-economic and environmental analyses of sustainable public transport in the Philippines. Sustainability, 12(11), 4720.

Beutel, J. (2017), The supply and use framework of national accounts. In: Handbook of Input-Output Analysis. United Kingdom: Edward Elgar Publishing. p41-132.

Bistline, J.E.T., Blanford, G., Grant, J., Knipping, E., McCollum, D.L., Nopmongcol, U., Scarth, H., Shah, T., Yarwood, G. (2022), Economy-wide evaluation of CO_2 and air quality impacts of electrification in the United States. Nature Communications, 13(1), 6693.

Borgstedt, P., Neyer, B., Schewe, G. (2017), Paving the road to electric vehicles - A patent analysis of the automotive supply industry. Journal of Cleaner Production, 167, 75-87.

Bravo, Y., Duarte, R., Sarasa, C. (2024), Economic and environmental impacts of the shifts to electromobility in Spain: A multiregional input-output framework. Journal of Industrial Ecology, 28(6), 1743-1754.

Cabrer, B., Contreras, D., Miravete, E. (1991), Aggregation in input-output tables: How to select the best cluster linkage. Economic Systems Research, 3(2), 99-110.

Černý, M., Bruckner, M., Weinzettel, J., Wiebe, K., Kimmich, C., Kerschner, C., Hubacek, K. (2022), Employment effects of the renewable energy transition in the electricity sector: An input-output approach. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4013339

Chen, C.H., Huang, Y.H., Wu, J.H., Lin, H. (2023), Assessing the cross-sectoral economic-energy-environmental impacts of electric-vehicle promotion in Taiwan. Sustainability, 15(19), 14135.

Chen, W., Sun, X., Liu, L., Liu, X., Zhang, R., Zhang, S., Xue, J., Sun, Q., Wang, M., Li, X., Yang, J., Hertwich, E., Ge, Q., Liu, G. (2022), Carbon neutrality of China's passenger car sector requires coordinated short-term behavioral changes and long-term technological solutions. One Earth, 5(8), 875-891.

Eisenberg, R., Gray, H.B., Crabtree, G.W. (2020), Addressing the challenge of carbon-free energy. Proceedings of the National Academy of Sciences, 117(23), 12543-12549.

Fragkiadakis, K., Charalampidis, I., Fragkos, P., Paroussos, L. (2020), Economic, trade and employment implications from EVs deployment and policies to support domestic battery manufacturing in the EU. Foreign Trade Review, 55(3), 298-319.

Hoehne, C., Muratori, M., Jadun, P., Bush, B., Yip, A., Ledna, C., Vimmerstedt, L., Podkaminer, K., Ma, O. (2023), Exploring decarbonization pathways for USA passenger and freight mobility. Nature Communications, 14(1), 6913.

IEA. (2023), Global CO_2 Emissions by Sector, 2019-2022. Available from: https://www.iea.org/data-and-statistics/charts/global-co2-emissions-by-sector-2019-2022

IEA. (2024), Global EV Outlook 2024. Available from: https://www.iea.org/reports/global-ev-outlook-2024

Jia, C., Ding, C., Chen, W. (2023), Research on the diffusion model of electric vehicle quantity considering individual choice. Energies, 16(14), 5423.

Junius, T., Oosterhaven, J. (2003), The solution of updating or regionalizing a matrix with both positive and negative entries. Economic Systems Research, 15, 87-96.

Koniak, M., Jaskowski, P., Tomczuk, K. (2024), Review of economic, technical and environmental aspects of electric vehicles. Sustainability, 16(22), 9849.

Kurkin, A., Kryukov, E., Masleeva, O., Petukhov, Y., Gusev, D. (2024), Comparative life cycle assessment of electric and internal combustion engine vehicles. Energies, 17(11), 2747.

Leard, B., Greene, D. (2023), Coordinating the electric vehicle transition and electricity grid decarbonization in the U.S. is not essential to achieving substantial long-term carbon dioxide emissions reductions. Environmental Research Letters, 18(7), 074035.

Lind, D.A., Marchal, W.G., Wathen, S.A. (2005), Statistical Techniques in Business and Economics. 12th ed. United States: McGraw-Hill.

Malaysian Automotive Association. (2025), Market Review for 2024. Available from: https://www.maa.org.my/pdf/2024/market_review_2024.pdf

Miller, R.E., Blair, P.D. (2009), Input-Output Analysis: Foundations and Extensions. Cambridge: Cambridge University Press.

Ministry of Environment and Water (KASA). (2021), Low Carbon Mobility Blueprint 2021-2023: Decarbonising land transportation. Available from: https://www.mgtc.gov.my/what/we-do/low-carbon-mobility-2/low-carbon-mobility/blueprint

Ministry of International Trade and Industry (MITI). (2020), National Automotive Policy (NAP) 2020. National Automotive Policy 2020 (NAP 2020). Available from: https://www.miti.gov.my/miti/resources/nap%202020/nap2020_booklet.pdf

Ministry of Investment, T. and I. (MITI). (2023), New Industrial Master Plan (NIMP) 2030. Available from: https://www.nimp2030.gov.my/nimp2030/modules_resources/bookshelf/nimp_20303/nimp_20303.pdf

Moore, R.E., Kearfott, R.B., Cloud, M.J. (2009), Introduction to Interval Analysis. United States: Society for Industrial and Applied Mathematics.

Muzir, N.A.Q., Mojumder, M.R.H., Hasanuzzaman, M., Selvaraj, J. (2022), Challenges of electric vehicles and their prospects in Malaysia: A comprehensive review. Sustainability, 14(14), 8320.

Nourelfath, M., Lababidi, H.M.S., Aldowaisan, T. (2022), Socio-economic impacts of strategic oil and gas megaprojects: A case study in Kuwait. International Journal of Production Economics, 246, 108416.

Ram, M., Aghahosseini, A., Breyer, C. (2020), Job creation during the global energy transition towards 100% renewable power system by 2050. Technological Forecasting and Social Change, 151, 119682.

Rocco, M.V., Casalegno, A., Colombo, E. (2018), Modelling road transport technologies in future scenarios: Theoretical comparison and application of Well-to-Wheels and Input-Output analyses. Applied Energy, 232, 583-597.

Sathiyan, S.P., Pratap, C.B., Stonier, A.A., Peter, G., Sherine, A., Praghash, K., Ganji, V. (2022), Comprehensive assessment of electric vehicle development, deployment, and policy initiatives to reduce GHG emissions: Opportunities and challenges. IEEE Access, 10, 53614-53639.

Shabadin, A., Johari, N.M., Jamil, H.M. (2014), Car Annual Vehicle Kilometer Travelled Estimated from Car Manufacturer Data-An Improved Method. In: Conference World Research & Innovation Convention on Engineering and Technology. Available from: https://www.researchgate.net/publication/281020242

Shafique, M., Azam, A., Rafiq, M., Luo, X. (2022), Life cycle assessment of electric vehicles and internal combustion engine vehicles: A case study of Hong Kong. Research in Transportation Economics, 91, 101112.

Sun, D., Liu, Y.Y., Yang, X.W., Lyu, L.Q., Yuan, J.H. (2022), Economic and employment effects of China's power transition based on input-output and scenario simulation. Advances in Climate Change Research, 13(5), 721-728.

Tamba, M., Krause, J., Weitzel, M., Ioan, R., Duboz, L., Grosso, M., Vandyck, T. (2022), Economy-wide impacts of road transport electrification in the EU. Technological Forecasting and Social Change, 182, 121803.

Tang, B., Xu, Y., Wang, M. (2022), Life cycle assessment of battery electric and internal combustion engine vehicles considering the impact of electricity generation mix: A case study in China. Atmosphere, 13(2), 252.

United Nations Framework Convention on Climate Change. (2022), Malaysia Biennial Update Report (BUR4). Available from: https://unfccc.int/documents/624776

Wang, N., Tang, G. (2022), A review on environmental efficiency evaluation of new energy vehicles using life cycle analysis. Sustainability, 14(6), 3371.

Weng, A., Ahmed, O.Y., Ehrlich, G., Stefanopoulou, A. (2024), Higher labor intensity in US automotive assembly plants after transitioning to electric vehicles. Nature Communications, 15(1), 8088.

Zhang, Y., Wu, D., Luo, G., Lv, H., Yang, P., Zhou, J., Liu, L. (2025), The impact of BEV manufacturing on China's economy and environment: An input-output perspective. Journal of Cleaner Production, 2025, 144773.

Zhao, Q., Chen, X., Chen, G., Qi, S. (2022), The socioeconomic contribution of the recreational fishery based on input-output analysis: The case of China. Marine Policy, 143, 105177.

Zheng, L., Tian, K. (2021), The contribution of ocean trade to national economic growth: A non-competitive input-output analysis in China. Marine Policy, 130, 104559.

Zheng, Y., Keith, D.R., Wang, S., Diao, M., Zhao, J. (2024), Effects of electric vehicle charging stations on the economic vitality of local businesses. Nature Communications, 15(1), 7437.

APPENDIX

Appendix 1: Sector aggregation (renamed using shortened naming convention, the number in brackets refer to the sector index in the original I-O table)

New code	New sectors	Original Sectors in the IO Table
1	PalmOilAgriAnimal	Paddy (1), Food Crops (2), Vegetables (3), Fruits (4), Rubber (5), Oil Palm (6), Flower Plants (7), Other Agriculture (8), Poultry Farming (9), Other Livestock (10)
2	ForestLog	Forestry and Logging (11)
3	FishAqua	Fishing and Aquaculture (12)
4	OilGasMining	Crude Oil and Natural Gas (13)
5	IronMining	Mining of Metal Ores (14)
6	StoneSandMining	Quarrying of Stone, Sand and Clay (15)
7	OthMining	Other Mining and Quarrying (16)
8	FoodProduct	Processing and Preserving of Meat (17), Processing and Preserving of Seafood (18), Processing and Preserving of Fruit & Vegetables (19), Dairy Products (20), Vegetable and Animal Oils and Fats (21), Grain Mill Products, Starches & Starch Products (22), Bakery Products (23), Confectionery (24), Other Food Processing (25), Prepared Animal Feeds (26)
9	BevTobacco	Spirit, Wine and Liquors (27), Soft Drinks, Minerals & Other Bottled Waters (28), Tobacco Products (29)
10	TextileLeather	Preparation, Spinning & Weaving of Textiles (30), Finishing of Textiles (31), Other Textiles (32), Wearing Apparel (33), Leather Products (34), Footwear (35)
11	WoodPaperPrint	Sawmilling & Planning of Wood (36), Veneer Sheets & Wood-based Panels (37), Builders' Carpentry & Joinery (38), Wooden Containers & Other Wood Products (39), Paper & Paper Products (40), Furniture (41), Reproduction of Recorded Media (42), Printing (43)
12	PetroleumProduct	Coke & Refined Petroleum Products (44)
13	ChemRubberPlastic	Basic Chemicals (45), Fertilizers & Nitrogen Compounds (46), Paints & Varnishes (47), Pharmaceuticals, Medicinal Chemical & Botanical Products (48), Soaps & Detergents, Cleaning & Polishing, Perfumes & Toilet Preparations (49), Other Chemical Products (50), Rubber Tyres & Tubes (51), Rubber Processing (52), Rubber Gloves (53), Other Rubber Products (54), Plastic Products (55)
14	MetalNonMetalProd	Glass & Glass Products (56), Refractory, Clay, Porcelain & Ceramic Products (57), Cement, Lime & Plaster (58), Other Non-Metallic Mineral Products (59), Basic Iron & Steel (60), Basic Precious & Other Non-Ferrous Metals (61), Casting of Metals (62), Structural Metal Products, Tanks, Reservoirs & Steam Generators (63), Other Fabricated Metal Products (64)
15	Engines	Engines & Turbines, Fluid-Power Equipment, Pumps etc., (65)
16	ElecElectronic	Other General Purpose Machinery (66), Weapons, Ammunition & Special Purpose Machinery (67), Domestic Appliances (68), Computers, Peripheral & Office Equipment (69) Fibre Optic, Electronic & Other Electric Cables (72), Electronic Components & Boards (74), Electronic Components & Boards (74), Communication Equipment & Consumer Electronics (75), Equipment for Irradiation, Electromedical & Electrotherapeutic (76), Measuring, Testing, Navigating & Control Equipment (77), Optical Instruments, Photographic Equipment & Magnetic/ Optical Media (78), Watches & Clocks (79)
17	ElecMotorBatteries	Electric Motors, Generators & Transformers (70), Electricity Distribution & Control Apparatus, Batteries & Accumulators (71)
18	MotorVehicle	Motor Vehicles, Trailers & Semi-Trailers (80)
19	TransportEquip	Motorcycles (81), Ships, Boats, Bicycles & Invalid Carriages (82), Other Transport Equipment (83), Other Manufacturing (84)
20	Electricity	Electricity and Gas (86)
21	WaterSewerWaste	Water (87), Sewerage, Waste Management & Remediation Activities (88)
22	Construction	Residential Buildings (89), Non-Residential Buildings (90)
23	CivilEngineer	Civil Engineering (91)
24	SpecialConstruction	Specialised Construction Activities (92)
25	WholesaleRetail	Wholesale & Retail Trade; Repair of Motor Vehicles & Motorcycles (93)
26	FoodAccom	Accommodation (94), Food and Beverage (95)
27	LandTrans	Land Transport (96)
28	TransportStorage	Water Transport (97), Air Transport (98), Warehousing & Support Activities for Transportation (99), Services Incidental to Water & Air Transportation (100), Highway, Bridge & Tunnel Operation Services (101)
29	ICT	Postal & Courier Activities (102), Publishing Activities (103), Telecommunications (104), Motion Picture, Programming & Broadcasting Activities (105), Computer & Information Services (106)
30	Finance	Monetary Intermediation (107), Other Financial Service (108), Insurance/Takaful & Pension Funding (109), Activities Auxiliary to Financial Service & Insurance/Takaful (110)
31	RealEstate	Real Estate (111), Ownership of Dwellings (112)
32	RentalLease	Rental and Leasing (113)
33	ResearchDev	Scientific Research & Development (114)
34	BusinessServ	Professional (115), Business Services (116)
35	Education	Education (118)
36	Health	Health (119)
37	GovernmentServ	Public Administration (117), Public Order & Safety (120), Other Public Administration (121)
38	NPISH	Non-Profit Institutions Serving Households (122)
38	OthServ	Arts, Entertainment & Recreation (123), Other Private Services (124)
39	EVManufacturing	[New sector]

Appendix 2: Top 15 contributing sectors for Malaysia's motor vehicle and EV manufacturing industry

Motor vehicle manufacturing		Ranking	EV manufacturing	
Sectors	**Contribution to Multiplier**		**Sectors**	**Contribution to multiplier**
MotorVehicle	1.25	1	EVManuf	1.19
WholesaleRetail	0.16	2	ElecElectronic	0.38
MetalNonMetalProd	0.10	3	ElecMotorBatteries	0.17
ChemRubberPlastic	0.09	4	WholesaleRetail	0.10
ElecElectronic	0.09	5	MetalNonMetalProd	0.07
BusinessServ	0.05	6	ChemRubberPlastic	0.04
PetroleumProduct	0.04	7	BusinessServ	0.03
Finance	0.03	8	Electricity	0.03
Electricity	0.02	9	PetroleumProduct	0.02
OilGasMining	0.02	10	Finance	0.02
LandTrans	0.01	11	OilGasMining	0.01
TransportEquip	0.01	12	LandTrans	0.01
TransportStorage	0.01	13	TransportEquip	0.01
SpecialConstruction	0.01	14	TransportStorage	0.01
Others	0.05	15	Others	0.04
Total Output Multiplier	1.95			2.12

Source: Author's calculation

Appendix 3: Top 15 contributing sectors for Malaysia's petroleum products and electricity industry

Petroleum products		Ranking	Electricity sectors	
Sectors	**Contribution to multiplier**		**Sectors**	**Contribution to multiplier**
PetroleumProduct	1.05	1	Electricity	1.02
OilGasMining	0.44	2	PetroleumProduct	0.16
WholesaleRetail	0.14	3	SpecialConstruction	0.10
ChemRubberPlastic	0.05	4	WholesaleRetail	0.08
Finance	0.02	5	OilGasMining	0.07
BusinessServ	0.02	6	BusinessServ	0.03
ElecElectronic	0.01	7	ElecElectronic	0.02
LandTrans	0.01	8	Finance	0.02
TransportStorage	0.01	9	ChemRubberPlastic	0.02
Electricity	0.01	10	MetalNonMetalProd	0.02
MetalNonMetalProd	0.01	11	ICT	0.01
SpecialConstruction	0.01	12	TransportStorage	0.01
ICT	0.00	13	LandTrans	0.01
MotorVehicle	0.00	14	OthMining	0.01
Others	0.02	15	Others	0.03
Total Output Multiplier	1.81			1.59

Scenario 1.1 refers to a decrease in demand for petroleum; scenario 1.2 refers to an increase in demand for electricity; scenario 1.3 refers to the net effect of scenarios 1.1 and 1.2. Scenario 2.1 refers to a decrease in demand for ICE Vehicles; scenario 2.2 refers to an increase in demand for EVs; scenario 2.3 refers to the net effect of scenarios 2.1 and 2.2 .

Source: Author's calculation