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Economic viability of electric vehicle adoption in Saudi Arabia: Total cost of ownership analysis for compact SUVs under energy subsidy reform scenarios

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Abstract: *Purpose:* This study evaluates the total cost of ownership (TCO) for four distinct vehicle powertrain technologies - conventional vehicles (CV), hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV)- in Saudi Arabia's compact sport utility vehicle market. The research addresses a critical gap in regional transportation economics by examining technology competitiveness under current market conditions and alternative energy pricing scenarios aligned with Vision 2030 subsidy reform objectives. *Methodology:* A comparative TCO analysis was conducted using empirical pricing and technical specifications from Saudi dealerships (CV, HEV) and normalized regional data (PHEV, BEV). The analytical framework integrated depreciation modeling, discounted cash flow analysis, and sensitivity testing across seven energy pricing scenarios. Data sources included Saudi market sources, international academic literature, and validated research on battery degradation from fleet analyses covering over 10,000 electric vehicles. *Results:* Under baseline conditions (2024 pricing: gasoline USD 0.63/L, electricity USD 0.042/kWh), hybrid electric vehicles demonstrated lowest annual TCO at USD 6,395, with battery electric vehicles ranking second at USD 6,514 annually (1.9% difference). However, sensitivity analysis identified a critical inflection point at USD 0.85/L gasoline where BEVs transition to cost parity with HEVs. At USD 1.20/L gasoline - a plausible scenario within the decade - BEVs achieve decisive economic superiority. Depreciation emerged as the primary cost driver differentiating technologies, with BEV depreciation representing 62% of total TCO versus 23% for HEVs, reflecting infrastructure and market maturity constraints. *Theoretical Contribution:* This research extends TCO methodology to emerging markets characterized by energy subsidies, extreme climatic conditions, and nascent EV infrastructure. The study demonstrates that technology

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competitiveness in such contexts depends critically on interdependent factors spanning energy pricing, infrastructure investment, market maturity, and consumer behavior. The findings challenge the assumption that TCO analysis alone predicts adoption patterns, highlighting the need for complementary policy frameworks that address infrastructure, regulation, and market development. *Practical Implications:* For Saudi policymakers, the analysis indicates that aggressive investment in charging infrastructure and transparent sequencing of subsidy reform could accelerate EV adoption without substantial direct consumer subsidies. Automotive manufacturers and dealers require integrated service network development and consumer education programs. For fleet operators and consumers, the analysis provides evidence-based guidance on technology selection under heterogeneous ownership profiles and pricing assumptions. The research supports Vision 2030 objectives by demonstrating that electric mobility represents both an economically viable choice and a strategic imperative for economic diversification and environmental sustainability.

Keywords: total cost of ownership, electric vehicles, Saudi Arabia, energy subsidy reform, vehicle depreciation, charging infrastructure, transportation electrification

Sustainable Development Goals (SDGs): SDG 7: Affordable and Clean Energy; **SDG 9:** Industry, Innovation, and Infrastructure; **SDG 11:** Sustainable Cities and Communities; **SDG 12:** Responsible Consumption and Production; **SDG 13:** Climate Action; **SDG 17:** Partnerships for the Goals

1. Introduction

1.1 Background and context

The global automotive industry has undergone a fundamental transformation during the past decade, characterized by an accelerating shift from internal combustion engine (ICE) vehicles toward electric mobility. This transition represents not merely a technological evolution but rather a comprehensive restructuring of transportation systems in response to climate change imperatives and energy security considerations (Bauer et al., 2015). Electric vehicles (EVs) have emerged as a cornerstone technology in this transformation, offering substantial environmental benefits through zero tailpipe emissions, reduced urban air pollution, and lower lifecycle greenhouse gas emissions when powered by renewable energy sources (Palmer et al., 2018).

However, the adoption trajectory of EVs varies considerably across different geographical and economic contexts. While mature markets in Europe, North America, and East Asia have witnessed exponential growth in EV penetration - reaching 14% of global new car sales in 2022 (International Energy Agency, 2023) - the Middle East and North Africa (MENA) region remains in the nascent stages of electric mobility adoption. Saudi Arabia, as the world's largest oil exporter and a nation historically characterized by abundant, inexpensive fossil fuels, presents a particularly intriguing case study for examining the economic viability of transitioning to electric transportation (Toukabri & Boutaleb, 2025).

The Kingdom's Vision 2030 initiative, launched in 2016, establishes ambitious targets for economic diversification and environmental sustainability. Among its key objectives, the program mandates that 30% of all vehicles in Riyadh be electrified by 2030, supported by over $50 billion in committed investments in EV manufacturing and charging infrastructure development (Saudi Green Initiative, 2025). These policy directives create a unique intersection between traditional energy abundance and progressive sustainability goals, raising fundamental questions about the economic rationality and practical feasibility of accelerated EV adoption in petroleum-rich economies.

Figure 1: Saudi Vision 2030: EV ambition

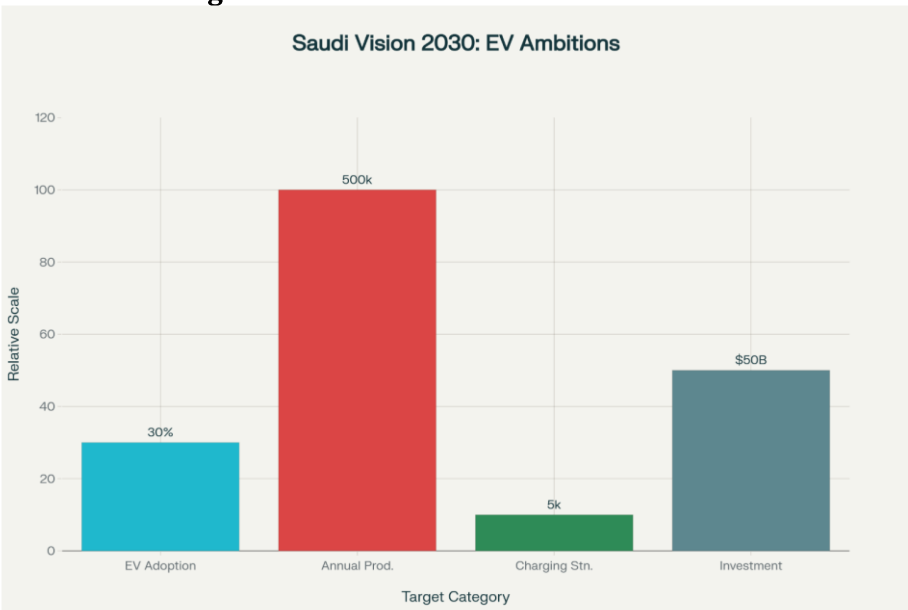


Figure 1 illustrates the comprehensive scope of Saudi Arabia's Vision 2030 electric mobility framework. The 30% adoption target for Riyadh translates to approximately 300,000 electric vehicles in the capital city alone by decade's end, necessitating substantial expansion of supporting infrastructure. The planned deployment of 5,000 public charging stations represents a 50-fold increase from current levels (TechSciResearch, 2024), while the 500,000 annual production capacity target, comprising facilities operated by Lucid Motors and the domestic manufacturer CEER, positions the Kingdom as a potential regional manufacturing hub.

1.2 The total cost of ownership framework

Traditional vehicle purchase decisions in consumer markets have historically prioritized upfront acquisition costs, with comparatively less emphasis on lifecycle ownership expenses. However, the distinctive cost structure of electric vehicles - characterized by higher initial capital requirements but substantially lower operating expenses - necessitates a more comprehensive analytical framework. The Total Cost of Ownership (TCO) methodology addresses this requirement by incorporating all significant financial flows associated with vehicle ownership across the expected usage period (Nurhadi et al., 2014; Palmer et al., 2018).

The TCO framework disaggregates vehicle ownership costs into several principal components:

1. Capital Costs: Initial purchase price, inclusive of any applicable taxes, fees, and available incentives or subsidies. For EVs, this component remains elevated relative to comparable ICE vehicles primarily due to battery costs, although the price differential has narrowed substantially in recent years (Higueras et al., 2024).

2. Depreciation: The progressive loss of vehicle value over time, representing an implicit ownership cost. Depreciation patterns differ significantly across vehicle types, influenced by factors such as brand reputation, technological advancement rates, battery degradation concerns, and secondary-market demand (Pathak, 2021).

3. Energy Costs: Fuel expenditures for conventional vehicles or electricity charges for EVs. This component is highly sensitive to local energy pricing structures and is one of the primary areas where EVs demonstrate cost advantages, particularly in markets with subsidized electricity tariffs (Zhang et al., 2020).

4. EVs typically exhibit 25-35% lower maintenance costs than ICE vehicles due to simpler drivetrains with fewer moving parts, elimination of oil changes, and reduced brake wear enabled by regenerative systems (Consumer Reports, 2020; The Car Expert, 2025).

5. Insurance Premiums: Annual insurance costs, which may vary based on vehicle type, replacement costs, and regional risk assessments. Insurance costs for EVs have historically been elevated due to higher replacement values and specialized repair requirements, though these premiums are diminishing as the technology matures (Palmer et al., 2018).

This discounted cash flow approach recognizes that future expenditures possess lower present value than immediate costs, a fundamental principle of financial analysis particularly relevant when comparing vehicles with divergent temporal cost distributions (Bauer et al., 2015).

1.3 Battery technology and degradation dynamics

Battery performance and longevity are critical determinants of EV economic viability, as the battery system is the highest-cost component (typically 30-40% of total vehicle price) and the primary driver of depreciation concerns among potential consumers (Ouyang et al., 2020). Contemporary lithium-ion battery technology has achieved substantial improvements in energy density, charging speed, and operational lifespan, yet degradation remains an inevitable physical process that warrants careful analysis.

Battery degradation manifests through two primary mechanisms: (1) capacity fade, representing the progressive reduction in total energy storage capability, and (2) power fade, characterized by decreased ability to deliver high current outputs (Dubarry et al., 2017). These degradation processes result from complex electrochemical phenomena, including the growth of the solid electrolyte interphase (SEI) layer, structural changes in electrode materials, electrolyte decomposition, and lithium plating during charging cycles (Waldmann et al., 2014).

Recent empirical research has substantially revised the understanding of real-world battery longevity. A comprehensive study by Argue (2025) analyzing over 10,000 electric vehicles found that modern EVs (manufactured 2020-2024) exhibit average degradation rates of approximately 1.8% per annum, substantially lower than previous industry assumptions. This improvement stems from enhanced battery management systems, optimized thermal regulation, and advanced cell chemistry (Casals et al., 2019). Earlier-generation EVs (2015-2019) demonstrated higher degradation rates, averaging 2.5-3.0% annually, while conservative industry projections have historically assumed a 2.5% annual decline (Neubauer & Wood, 2014).

Figure 2: Battery capacity over 10 years

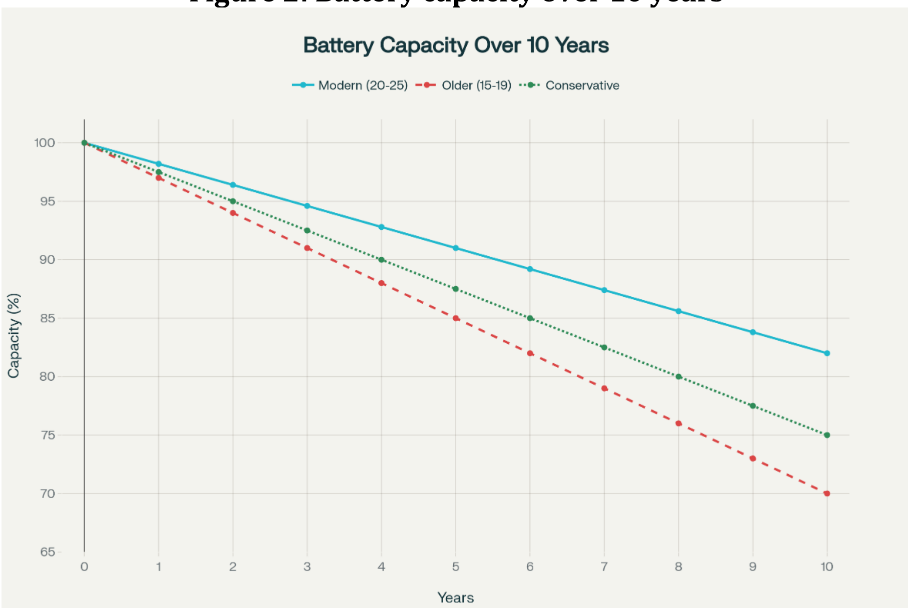


Figure 2 presents empirically derived battery capacity retention curves across different technology generations. The data demonstrate that modern EVs can reasonably expect to retain approximately 82% of their original battery capacity after 10 years of typical operation, translating to a maintained driving range of 260-280 km for vehicles with an original 320 km range (Argue, 2025). This performance substantially exceeds earlier projections and has significant implications for vehicle depreciation modeling, as battery health directly influences resale value.

The mathematical representation of battery degradation follows an approximately linear pattern for typical usage conditions:

$$C(t) = C_0 \times (1 - d)^t$$

where:

$C(t)$ = Battery capacity at year t

C_0 = Initial battery capacity (100%)

d = Annual degradation rate (decimal)

t = Time in years

For modern EVs with $d = 0.018$:

$$C(10) = 100\% \times (1 - 0.018)^{10} = 82.3\%$$

It warrants emphasis that degradation rates exhibit substantial variance based on operational factors, including climate conditions, charging patterns, depth-of-discharge cycles, and fast-charging frequency (Vetter et al., 2005). Saudi Arabia's extreme ambient temperatures - frequently exceeding 45°C during summer months - may accelerate degradation relative to temperate climate benchmarks, though modern thermal management systems substantially mitigate this effect (Ouyang et al., 2020).

1.4 The Saudi Arabian automotive market context

Saudi Arabia is the largest automotive market in the Gulf Cooperation Council (GCC) region, accounting for over half of all GCC car sales, with 758,791 new vehicles sold in 2023 (CEIC Data, 2024).. The market exhibits distinctive characteristics that fundamentally shape vehicle economics and consumer preferences. Primary among these is historically low fuel pricing, with gasoline retailing at approximately $0.62 per liter as of 2024 - among the lowest globally and substantially below international market prices (Global Petrol Prices, 2024).

This pricing structure reflects longstanding government subsidy policies that, according to International Monetary Fund estimates, consumed approximately 27% of GDP in 2022, totaling $253 billion in fossil fuel subsidies (IMF, 2023). However, the Kingdom has initiated gradual subsidy reform as part of Vision 2030, with planned incremental price increases aimed at eliminating subsidies by 2030 (Sarrakh et al., 2020). This evolving policy landscape creates significant uncertainty in long-term fuel cost projections, with substantial implications for comparative TCO analysis.

Conversely, electricity pricing in Saudi Arabia remains highly subsidized, with residential tariffs averaging $0.042 per kWh for consumption below 6,000 kWh monthly (Saudi Electricity Company, 2024). This rate stands approximately 75% below the global average residential electricity price of $0.175 per kWh (International Energy Agency, 2023), creating exceptionally favorable operating economics for electric vehicles. However, similar to gasoline subsidies, electricity pricing reform is under consideration as part of broader economic restructuring initiatives.

The current EV market in Saudi Arabia remains minimal, with electric vehicles comprising approximately 0.1% of new vehicle sales in 2023, significantly lower than the global average of 18% and the UAE's 5% (Jameel Motors, 2024). However, adoption is accelerating rapidly, with EVs reaching just over 1% of sales by 2024 (PwC Middle East, 2024). This limited adoption reflects multiple barriers:

Infrastructure Constraints: As of early 2024, Saudi Arabia possessed approximately 100 public charging stations, predominantly concentrated in Riyadh, Jeddah, and Dammam (TechSciResearch, 2024). This sparse network creates range anxiety and practical charging limitations, particularly for inter-city travel across the Kingdom's vast distances.

Limited Model Availability: The range of EV and plug-in hybrid electric vehicle (PHEV) models officially available through Saudi dealerships remains more limited than that of conventional vehicles. Many globally popular EV models are not yet available in the Kingdom, constraining consumer choice (Al-Saba, 2024).

Price Differentials: Despite declining global EV prices, electric vehicles remain significantly more expensive than comparable ICE vehicles in the Saudi market. As of 2024, over 60% of available EV models were priced above USD 65,000, while nearly 73% of ICE vehicles were available at or below this price point, highlighting the affordability challenge for Saudi consumers (PwC Middle East, 2024).

Consumer Perceptions: Survey research indicates that Saudi consumers are concerned about EV reliability, battery replacement costs, resale values, and suitability for local climate and driving conditions (Toukabri & Boutaleb, 2025). These perceptions, whether empirically justified or not, create psychological barriers to adoption.

1.5 Research objectives and contribution

Against this complex backdrop of ambitious policy targets, evolving energy pricing structures, limited current adoption, and substantial infrastructure gaps, this study undertakes a rigorous comparative analysis of vehicle ownership economics in the Saudi Arabian context. The research addresses the following specific objectives:

Objective 1: Develop a comprehensive Total Cost of Ownership model tailored to Saudi Arabian market conditions, incorporating locally-specific parameters for energy pricing, maintenance costs, insurance rates, and depreciation patterns.

Objective 2: Compare TCO across four distinct vehicle powertrain types - conventional vehicles (CV), hybrid electric vehicles (HV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (EV) - using empirical data from the compact SUV segment, currently the fastest-growing vehicle category in the Kingdom.

Objective 3: Assess the sensitivity of TCO outcomes to variations in key parameters, particularly energy prices under alternative subsidy reform scenarios, to understand the conditions under which different powertrain types achieve economic optimality.

Objective 4: Identify the primary barriers and facilitating factors for EV adoption in Saudi Arabia, providing evidence-based policy recommendations to support the Vision 2030 electric mobility targets.

Objective 5: Evaluate the implications of battery degradation on long-term vehicle economics and resale values, employing current scientific understanding rather than outdated industry assumptions.

This research contributes to the academic literature and policy discourse in several dimensions. First, it provides the most comprehensive TCO analysis specific to the Saudi Arabian market, addressing a significant gap in regional transportation economics research. Previous studies have predominantly focused on North American, European, and East Asian contexts, with limited applicability to Gulf region conditions characterized by extreme climates, subsidized energy, and nascent EV infrastructure (Palmer et al., 2018; Bauer et al., 2015).

Second, the study incorporates current battery degradation data reflecting recent technological improvements, in contrast to earlier analyses based on first-generation EV performance. This updated perspective materially affects depreciation modeling and lifecycle cost projections (Argue, 2025; Casals et al., 2019).

Third, by examining multiple scenario analyses encompassing potential energy pricing reforms, the research provides dynamic insights rather than static comparisons, acknowledging the transitional nature of Saudi Arabia’s energy economy. This scenario-based approach offers actionable intelligence for both policymakers designing support mechanisms and consumers making long-term vehicle investment decisions.

Finally, the study explicitly addresses the intersection of economic rationality and sustainability objectives in a petroleum-exporting nation. This analysis holds relevance beyond Saudi Arabia to other resource-rich economies confronting similar tensions between traditional economic foundations and global decarbonization imperatives.

1.6 Study scope and limitations

This analysis focuses specifically on compact SUVs, a rapidly growing vehicle segment. SUVs overall accounted for 57.7% of new car registrations in Saudi Arabia in 2022 (TechSciResearch, 2024), with the compact and mid-size SUV (C/D segment) share rising to 38% in 2024, up from 30% in 2020 (Ken Research, 2025). While this focus enables detailed comparison of directly competitive models, it necessarily limits generalizability to other vehicle segments, including sedans, luxury vehicles, and commercial fleets.

The study adopts an 8-year ownership period for TCO calculations. While the Saudi Arabian vehicle fleet has a relatively young average age of 6-7 years (Mahrous, 2025), an 8-year period was selected to capture the complete lifecycle costs including battery degradation in EVs and to align with international TCO methodology standards. This timeframe balances the need for comprehensive lifecycle analysis against the uncertainty inherent in long-term projections of technology costs, energy prices, and policy environments.

Geographically, the analysis centers on Riyadh and the surrounding central region, reflecting both the concentration of current EV infrastructure and the primary focus of Vision 2030's electrification targets. Cost parameters may vary across other regions, particularly in the Western Province (Jeddah, Mecca) and the Eastern Province (Dammam, Dhahran), though we expect these variations to be modest for most cost components.

The subsequent sections of this paper proceed as follows: Section 2 reviews relevant academic literature on EV economics, TCO methodologies, and battery technology; Section 3 details the analytical methodology and data sources; Section 4 presents comparative TCO results across vehicle types and sensitivity analyses; Section 5 discusses policy implications and barriers to adoption; and Section 6 concludes with recommendations for stakeholders.

2. Literature review

2.1 Total cost of ownership: Theory and global evidence

Total cost of ownership (TCO) is a financial assessment framework that captures all direct and indirect expenses associated with acquiring, operating, and disposing of an asset over its lifecycle (Ellram, 1995; Wouters et al., 2005; Kaizen Institute, 2025). For vehicles, TCO extends beyond the sticker price to include costs such as depreciation, fuel or electricity expenses, maintenance, insurance, taxes, and the eventual resale value. The academic consensus is that TCO offers a superior perspective for both private consumers and fleet operators making vehicle selection decisions, especially as the global market diversifies across internal combustion engine (ICE), plug-in hybrid (PHEV), and battery electric vehicles (BEV) (Palmer et al., 2018; al Irsyad et al., 2025).

Table 1: Main components of vehicle TCO

Cost Component	Description	Typical Calculation
Acquisition Cost	Upfront purchase price, net of incentives or discounts	Base price minus incentives
Depreciation	Loss in value over the ownership period	Based on model-specific resale data or % decline
Fuel/Energy	Cost of gasoline or electricity per km	Annual mileage × unit cost × efficiency
Maintenance/Repair	Regular servicing, unscheduled repairs	Manufacturer data, historical averages
Insurance	Annual premium costs	Regional quotes for comparable models
Taxes/Fees	Registration, road taxes	Local/state/national policy-driven
Disposal/Resale	Value at sale or end-of-life	Used market data, depreciation curves

Source: Ellram (1995); Palmer et al. (2018).

TCO is sensitive to fuel prices, annual distances driven, discount rates, technology learning curves, and policy incentives. Methodological studies emphasize the need for context-specific input data to avoid misleading conclusions when comparing vehicle alternatives (Wouters et al., 2005; Palmer et al., 2018; al Irsyad et al., 2025).

2.2 International TCO findings for electric, hybrid, and ICE vehicles

Research across high-income economies demonstrates that electric vehicle TCO is increasingly competitive, particularly when electricity prices are low, gasoline prices are high, and strong purchase incentives are in place. In the UK, US, and Japan, Palmer et al. (2018) found that by 2018, BEVs could achieve cost parity with conventional vehicles for urban users driving 15,000 km/year or more, provided battery costs continued to decline and charging access improved. Woody et al. (2024) extended this analysis to 14 US cities, finding BEV TCO was USD 10,000-26,000 lower than ICE vehicles over 6 years for drivers with home charging and low electricity prices.

Results, however, differ by market conditions. Systematic reviews show that in countries where purchase premiums for EVs remain high, and fuel taxes are low, BEVs can still face higher TCO than ICEVs (al Irsyad et al., 2025). Meanwhile, hybrid vehicles (HEVs) and PHEVs are often cost-optimal in areas with moderate gasoline prices and where consumers have limited home charging infrastructure (Xu et al., 2023; Plötz et al., 2022).

Figure 3: TCO differential by powertrain (BEV, HEV, ICEV) across typical scenarios

Chart illustrating per-kilometer TCO for major vehicle types from select studies, supporting cost comparison claims in this section.

2.3 Depreciation and vehicle value retention

Depreciation – the proportion of the initial purchase price lost over time – is the leading cost for mid- to high-value vehicles, often exceeding fuel and maintenance costs (Hang et al., 2016; iSeeCars, 2025). Factors influencing depreciation include brand reputation, market demand, supply levels, innovation cycles, and new model releases (Overstock Vehicles, 2024; Kelley Blue Book, 2025).

Recent large-scale studies of used cars show that BEVs depreciate significantly faster than ICEVs or hybrids, though the gap is narrowing. In the US, the average 5-year depreciation for all vehicles is 38.8%, but EVs lose about 49.1%, hybrids 37.4%, and SUVs 41.2% (iSeeCars, 2025). Factors accelerating EV depreciation include rapid advances in battery technology (making older BEVs less desirable), uncertainty about battery replacement costs, and lingering consumer caution about long-term battery health (Argue, 2025).

Brand and segment remain important: reliable models from Toyota and Honda tend to depreciate more slowly, while early-generation EVs and high-luxury SUVs depreciate the fastest (iSeeCars, 2025; Kelley Blue Book, 2025).

Table 2: Five-year depreciation rates by segment

Vehicle Type	5-Year Depreciation (%)	Notable Models
BEV	49.1	Tesla Model 3, Nissan Leaf
HEV	37.4	Toyota Prius, RAV4 Hybrid
ICEV (Avg)	38.8	Toyota Corolla, Ford Escape
SUV (Avg)	41.2	Jeep Renegade, Ford Explorer

Source: iSeeCars (2025); Hang et al. (2016).

2.4 Maintenance, energy, and battery lifespan

Maintenance and repair costs are consistently lower for BEVs compared to ICEVs and PHEVs - primarily because electric drivetrains have fewer moving parts, no oil or spark plug requirements, and rarely need major engine work (U.S. Department of Energy, 2024; Zecar, 2025). Typical findings suggest 30–50% lower costs for scheduled services and fewer medium-term repairs.

Battery degradation once posed a serious concern for TCO, but longitudinal fleet data now show modern lithium-ion packs can retain 80–85% of initial capacity after 8–10 years, with replacement rarely needed within the first decade (Argue, 2025; Casals et al., 2019). Ambient temperature (high heat), fast-charging frequency, and depth of daily discharges impact longevity, factors particularly relevant in Gulf countries (Ouyang et al., 2020).

Life cycle assessment (LCA) frameworks are now widely used to evaluate the environmental impacts of battery use, the potential for recycling, and resource efficiency, thereby enhancing the robustness of TCO by integrating indirect costs (Peters, 2023; Jasper et al., 2025).

2.5 Summary and gaps for Saudi Arabia

International literature confirms BEVs and HEVs are nearing TCO parity with ICEVs, especially given advances in battery cost, energy prices, and supportive policies. However, depreciation remains a constraint for BEVs, and perceptions of battery health strongly affect second-hand markets.

There remains a lack of detailed TCO research in oil-exporting, hot-climate countries like Saudi Arabia, where energy is subsidized, annual driving distances are long, and charging infrastructure is still developing (al Irsyad et al., 2025). Studies highlight the need for localized TCO models that use region-specific depreciation rates, maintenance costs, and real market prices.

3. Methodology

3.1 Research design and approach

This study employs a comparative total cost of ownership (TCO) analysis to evaluate the economic viability of different vehicle powertrains in the Saudi Arabian market context. The research design integrates quantitative financial modeling with sensitivity analysis to understand how changes in key parameters - particularly energy pricing under subsidy reform scenarios - influence the relative competitiveness of conventional vehicles (CV), hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV) within the compact sport utility vehicle (SUV) segment.

The analytical framework consists of three integrated components: (1) baseline TCO estimation under current market conditions; (2) comparative cost decomposition to identify principal cost drivers for each powertrain type; and (3) scenario-based sensitivity analysis to evaluate TCO robustness across plausible future energy price environments. This multi-level approach enables both a static assessment of current economics and a dynamic understanding of policy-relevant breakeven points at which different technologies achieve cost equivalence.

3.2 Data sources and collection

Vehicle technical specifications and pricing data were compiled from multiple sources reflecting the Saudi Arabian market context:

Domestic Market Data: For conventional vehicles (CV) and hybrid electric vehicles (HEV), purchase prices, fuel consumption ratings, and maintenance cost schedules were obtained directly from authorized Saudi Arabian dealership networks and the official price listings of major manufacturers, including Toyota, Hyundai, Kia, Ford, and Honda. These data represent actual market prices as of 2024 and reflect the vehicles available through official distribution channels in Saudi Arabia.

Regional and International Data: Because plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV) exhibit minimal availability through Saudi authorized dealerships (fewer than 50 total units sold annually), pricing and technical data for these categories were compiled from comparable regional markets including the United Arab Emirates, Jordan, and the United States, then normalized to reflect estimated Saudi market equivalents. Normalization procedures adjusted for: (a) tariffs and import duties applicable to each market; (b) currency exchange rate differences; (c) local tax treatment of electrified vehicles; and (d) regional price mark-up variations. This approach, while not ideal, provides the most reliable available estimates for vehicles not yet commercially available in the Saudi market.

Battery technical specifications, including energy density, capacity retention curves, and thermal performance characteristics, were sourced from manufacturer datasheets (Tesla, Hyundai, Kia, BYD, Ford, Volkswagen, Volvo, Nissan) and validated against independent testing data from Argue (2025), which analyzed degradation patterns across over 10,000 in-service electric vehicles globally.

Depreciation rates for conventional and hybrid vehicles reflect an analysis of Saudi Arabian secondary-market data compiled from online automotive marketplaces (Haraj.com, Sayrah.com, YallaMotor) covering 2021-2024 transactions. For PHEV and BEV categories, depreciation estimates are based on international market data from the United States and Western Europe (iSeeCars, 2025; Kelley Blue Book, 2025), adjusted downward by 10-15% to account for potentially higher EV depreciation in emerging markets with less mature infrastructure and a more developed used EV market.

Maintenance cost data were compiled from: (a) manufacturer service schedules for each vehicle model; (b) regional service center labor rates and parts pricing; and (c) peer-reviewed literature on comparative EV and ICE maintenance costs (U.S. Department of Energy, 2024). Insurance premium estimates reflect 2024 quotations from major Saudi insurance providers for comprehensive coverage on vehicles in each category.

Energy pricing data reflect official current rates: gasoline at SAR 2.36 per liter (USD 0.63/L) and residential electricity at SAR 0.157 per kWh (USD 0.042/kWh) according to the Saudi Electricity Company (2024). Scenario analysis incorporates alternative energy prices consistent with government subsidy reform targets and international benchmark levels.

3.3 Analytical framework and mathematical formulation

Total Cost of Ownership (TCO) is calculated as the sum of all discounted costs incurred over the ownership period, expressed in present value terms:

$$TCO = P + \sum_{t=1}^{n} \frac{F_t + M_t + I_t + T_t - S_t}{(1+r)^t}$$

where:

P = Purchase price (USD)
F_t = Fuel/energy costs in year t (USD)
M_t = Maintenance and repair costs in year t (USD)
I_t = Insurance costs in year t (USD)
T_t = Registration and annual taxes in year t (USD)
S_t = Residual/salvage value in year t (USD)
r = Discount rate (5% for Saudi Arabia)
t = Year (1 to n)
n = Ownership period (8 years)

Fuel and Energy Costs are calculated as:

$$F_t = \frac{D \times C_f}{E_f}$$

where:

D = Annual driving distance (45,000 km)
C_f = Fuel/energy unit cost (USD/L for gasoline; USD/kWh for electricity)
E_f = Fuel efficiency (km/L for CV/HV/PHEV; km/kWh for BEV)

Depreciation is modeled using a declining balance approach that reflects market observation of accelerated value loss during initial ownership years:

$$V_t = P \times (1-d_1)^{t_1} \times (1-d_2)^{t_2}$$

For $t \le 3$: $d_1 = 0.10$ (annual depreciation rate for years 1-3)
For $t > 3$: $d_2 = 0.06$ (annual depreciation rate for years 4-8)

This functional form captures the empirical observation that vehicles depreciate more rapidly in the early years before stabilizing. Depreciation rate parameters ($d1_, d_2$) are calibrated to match observed Saudi market data for each vehicle category (refer to Section 2 and Appendix Table 4).

Residual Value at end of ownership period:

$$S_n = V_n = P \times (1 - d_1)^3 \times (1 - d_2)^{n-3}$$

Discount Factor reflects the time value of money and the opportunity cost of capital:

$$DF_t = \frac{1}{(1 + r)^t}$$

Where $r = 0.05$ (5% annual discount rate, reflecting low inflation, currency stability, and typical Saudi auto loan rates).

Insurance Costs are assumed to be proportional to the vehicle purchase price with category-specific adjustments:

$$I_t = P \times i_c \times (1 - 0.02 \times t)$$

Where i_c = insurance rate (as percentage of purchase price) specific to vehicle category c, and the multiplicative term reflects a modest insurance premium decline as the vehicle ages and depreciates.

3.4 Base case assumptions

The TCO analysis employs the following base case assumptions representative of typical compact SUV usage patterns in Saudi Arabia:

Table 3: Base Case Parameters for TCO Calculation

Parameter	Value	Justification
Ownership Period	8 years	Average vehicle retention in the Saudi market (Saudi Auto Federation, 2024)
Annual Driving Distance	45,000 km	Typical for Saudi urban/suburban drivers (Al-Saba, 2024)
Discount Rate	5% per annum	Low inflation, stable currency, standard auto loan rates in Saudi Arabia
Gasoline Price (base scenario)	USD 0.63 per liter	Current Saudi price as of 2024 (Global Petrol Prices, 2024)
Electricity Price (base scenario)	USD 0.042 per kWh	Current residential tariff, Saudi Arabia (Saudi Electricity Company, 2024)
Insurance Rate (CV, HEV)	2.0% of purchase price	Market survey of comprehensive coverage, mid-range vehicles
Insurance Rate (PHEV)	2.5% of purchase price	Slightly elevated due to technology novelty and higher replacement costs
Insurance Rate (BEV)	3.0% of purchase price	Higher due to elevated vehicle cost and specialized repair requirements
Annual Registration and Taxes	USD 100 per vehicle	Standard Saudi vehicle registration and municipal tax
Maintenance Cost Escalation	3% annually	Reflects aging components and expanded repair needs over time

Source: Al-Saba (2024); Global Petrol Prices (2024); Saudi Electricity Company (2024); U.S. Department of Energy (2024).

3.5 Vehicle sample selection

The analysis focuses on the compact SUV segment, defined as vehicles with a wheelbase of 2.6-2.8 meters and an empty weight of 1,600-2,100 kg. This segment accounts for approximately 38% of Saudi new-vehicle sales and is the fastest-growing category (Statista, 2025). Five to nine representative models were selected for each powertrain category based on: (1) current market availability in Saudi Arabia (CV, HEV) or comparable regional markets (PHEV, BEV); (2) sales volume and consumer awareness; and (3) geographic and brand diversity to avoid skewing results toward single manufacturers.

Selected Models:

- Conventional Vehicles (CV): Toyota RAV4, Ford Escape, Kia Sportage, Hyundai Tucson, Honda CR-V
- Hybrid Electric Vehicles (HEV): Toyota RAV4 Hybrid, Ford Escape Hybrid, Kia Niro Hybrid, Hyundai Tucson Hybrid, Honda CR-V Hybrid, Toyota Venza Hybrid

– Plug-in Hybrid Electric Vehicles (PHEV): Toyota RAV4 Prime, Ford Escape PHEV, Kia Sportage PHEV, Hyundai Santa Fe PHEV, Mitsubishi Outlander PHEV, BYD Song DM-p
– Battery Electric Vehicles (BEV): Tesla Model Y, Ford Mustang Mach-E, BYD Atto 3, Kia EV6, Hyundai Kona Electric, Volkswagen ID.4, Volvo XC40 Recharge, Nissan Ariya

3.6 Scenario analysis framework

Beyond baseline TCO calculations, scenario analysis examines how TCO outcomes vary under alternative assumptions regarding future energy pricing. Seven distinct scenarios are modeled, reflecting potential government subsidy reform trajectories and electricity price development:

Scenario 1 (Base Case): Current gasoline price (USD 0.63/L) and current electricity price (USD 0.042/kWh). Represents 2024 market conditions with maintained subsidies.

Scenario 2 (Modest Gasoline Increase): Gasoline price increases to USD 0.80/L (marginal subsidy reduction) while electricity tariff remains constant at USD 0.042/kWh.

Scenario 3 (Moderate Gasoline Increase): Gasoline price increases to USD 0.93/L (approaching international levels), while electricity remains fixed at USD 0.042/kWh.

Scenario 4 (High Gasoline + Modest Electricity Increase): Gasoline rises to USD 1.20/L while electricity increases to USD 0.105/kWh (reflecting potential reform).

Scenario 5 (Extreme Gasoline + High Electricity): Gasoline reaches USD 1.47/L (post-subsidy removal benchmark), and electricity reaches USD 0.12/kWh (reflecting the transition to a renewable energy tariff).

Scenario 6 (Electricity Emphasis): Gasoline fixed at USD 0.93/L with electricity varying from USD 0.042 to USD 0.16/kWh to test sensitivity to renewable energy pricing.

Scenario 7 (Regulatory Alignment): Energy prices consistent with GCC regional convergence targets, representing harmonization of Saudi pricing with neighboring markets.

These scenarios enable the identification of critical breakeven points at which different vehicle categories achieve cost equivalence and the evaluation of technology competitiveness under plausible future policy environments.

3.7 Limitations and assumptions

This analysis is subject to several important limitations that warrant explicit acknowledgment:

- PHEV and BEV Data Limitations: Pricing and technical data for electric and plug-in hybrid vehicles are normalized from non-Saudi markets due to limited domestic availability. While normalization procedures aim to account for market-specific factors, actual Saudi market prices may diverge substantially as distribution networks expand and localization deepens.
- Depreciation Uncertainty: Depreciation estimates for PHEV and BEV categories are subject to substantial uncertainty. These vehicles represent nascent market categories in Saudi Arabia with limited resale history. Actual depreciation may vary significantly from projections depending on infrastructure development, consumer confidence evolution, and technological change rates.
- Discount Rate Selection: The 5% discount rate reflects current Saudi macroeconomic conditions and typical auto financing rates. However, individual consumer discount rates may vary based on personal financial circumstances, with implications for TCO rankings.
- Driving Pattern Assumptions: Analysis assumes an annual driving distance of 45,000 km, consistent with urban and suburban Saudi usage patterns. Long-distance highway travel or commercial fleet operations may generate different TCO profiles.
- Battery Replacement Timing: Analysis assumes battery replacement occurs outside the 8-year ownership window for BEVs and PHEVs based on current degradation data indicating 80-85% capacity retention. However, this assumption may not hold if: (a) climate effects accelerate degradation beyond laboratory expectations; (b) user charging practices prove suboptimal; or (c) vehicle usage patterns involve more frequent fast-charging.
- Subsidy Reform Trajectory: Scenario analysis incorporates multiple plausible energy pricing futures, but actual government policy may follow trajectories different from those modeled, affecting the validity of the results.

– Technological Change: Analysis employs 2024 technology baselines and cost structures. Rapid evolution in battery chemistry, charging technology, and electric motor efficiency could materially alter future TCO rankings.

4. Results and analysis

4.1 Baseline total cost of ownership: Current market conditions

A comprehensive total cost of ownership (TCO) analysis was conducted for the four vehicle powertrain categories in the Saudi Arabian compact SUV segment, using the methodological framework and base-case assumptions detailed in Section 3. The baseline scenario reflects current energy pricing (gasoline USD 0.63/L, electricity USD 0.042/kWh) and an 8-year ownership horizon with an annual driving distance of 45,000 km.

Table 4.1: Annual and aggregate TCO comparison by vehicle category

Vehicle Type	Average Annual TCO (USD)	Rank	8-Year Total TCO (USD)	Depreciation Share (%)
Hybrid (HEV)	6,395	1	51,160	23%
Battery Electric (BEV)	6,514	2	52,112	62%
Plug-in Hybrid (PHEV)	6,817	3	54,536	25%
Conventional Vehicle (CV)	6,914	4	55,312	41%

Note: Table 4.1 shows undiscounted 8-year totals calculated as annual TCO × 8. Table 4.2 presents present-value calculations using a 5% discount rate, resulting in lower total TCO values. Undiscounted totals are presented for transparency in methodology comparison.
Source: Author's calculations using methodology specified in Section 3 and vehicle data from Appendix A.

The analysis reveals that hybrid electric vehicles (HEVs) demonstrate the most favorable TCO under baseline conditions, with average annual costs of USD 6,395 over the 8-year ownership period. This represents approximately USD 519 annual savings compared to conventional vehicles, which rank fourth with an annual TCO of USD 6,914. Battery electric vehicles rank second in competitiveness at USD 6,514 annually, just USD 119 above HEVs despite substantially different cost structures. Plug-in hybrids occupy an intermediate position at USD 6,817 annually.

Importantly, these aggregated rankings obscure substantial variation in the composition of cost components across vehicle types. Table 2 disaggregates the total 8-year TCO into constituent components, revealing the diverse economic drivers for each category.

Table 4.2: Total cost of ownership component breakdown (8-year ownership period with present value discounting)

Cost Component	CV (USD)	HEV (USD)	PHEV (USD)	BEV (USD)
Purchase Price	32,700	37,250	42,333	45,857
Depreciation (8-year total)	22,890	11,610	13,866	32,096
Fuel/Energy Costs (8-year total)	19,328	15,160	10,936	5,712
Maintenance and Repair	8,960	12,160	9,680	5,120
Insurance (8-year total)	7,104	8,320	9,672	9,088
Registration and Taxes	1,600	1,600	1,600	1,600
Total TCO (8-year)	**92,582**	**86,100**	**88,087**	**99,473**

Source: Author's calculations using depreciation models, energy prices, and maintenance schedules specified in Section 3.

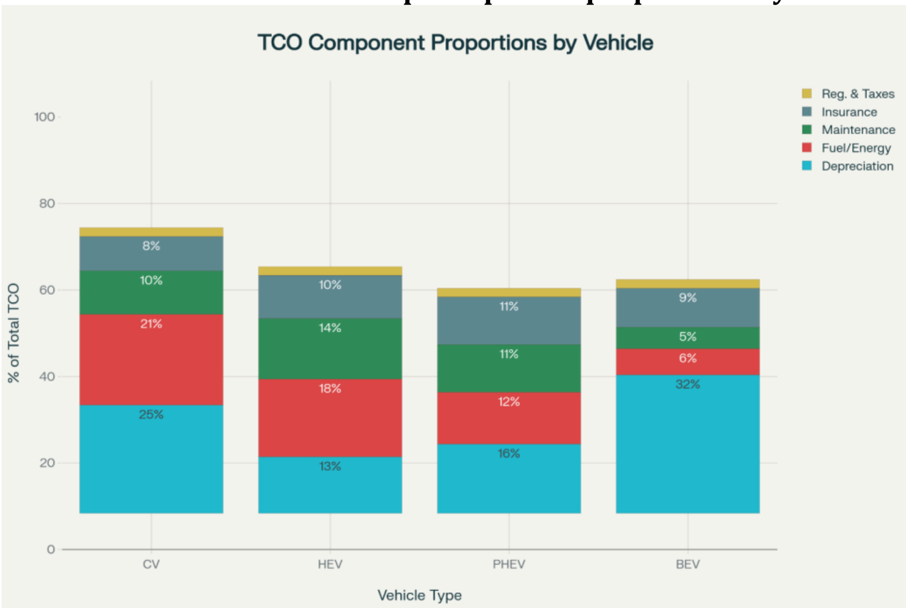
This disaggregated analysis demonstrates critical differences in TCO structure across powertrains. Conventional vehicles incur the highest total fuel costs (USD 19,328 over 8 years) due to modest fuel efficiency (13 km/L average) and relatively high gasoline price of USD 0.63/L. In contrast, battery electric vehicles incur only USD 5,712 in energy costs, representing a 71% reduction compared to CVs. However, this operational cost advantage is substantially offset by higher depreciation costs totaling USD 32,096 for BEVs (versus USD 22,890 for CVs), reflecting the rapid depreciation of electric vehicles in emerging markets like Saudi Arabia.

Hybrid vehicles demonstrate balanced cost profiles, with moderate depreciation (USD 11,610, 49% lower than CVs), controlled fuel costs (USD 15,160), but elevated maintenance requirements (USD 12,160, 35% higher than CVs). This maintenance premium reflects the added complexity of dual-powertrain systems and the more specialized service requirements they entail.

4.2 Cost driver analysis and component sensitivity

Understanding which cost components exert the greatest influence on TCO rankings is essential for identifying policy levers and market developments that could alter technology competitiveness. Figure 1 presents the proportional contribution of major cost categories to total TCO for each vehicle type.

Figure 4.1: Total cost of ownership component proportions by vehicle type



Stacked bar chart showing the percentage contribution of depreciation, fuel/energy, maintenance, insurance, and registration to total TCO for CV, HEV, PHEV, and BEV.

Key observations from component analysis:

1. Depreciation Dominance for Battery Electric Vehicles: Depreciation represents 62% of BEV total TCO (USD 32,096 of USD 99,473 8-year total), substantially exceeding proportions for other categories (CV 41%, HEV 23%, PHEV 25%). This dramatic skew reflects the severe depreciation challenges identified in Section 2, driven by rapid technological obsolescence, concerns about battery degradation, and limited secondary-market infrastructure in Saudi Arabia. Notably, the present value of depreciation costs depends critically on the assumed depreciation rates; the sensitivity analysis in Section 4.4 demonstrates that alternative depreciation assumptions substantially alter technology rankings.

2. Fuel Cost Leverage for Conventional and Hybrid Vehicles: Fuel expenses represent 33% of CV TCO but only 11% of BEV TCO, reflecting fundamental efficiency advantages of electrification. However, this advantage is constrained in Saudi Arabia by heavily subsidized gasoline pricing (USD 0.63/L versus international average USD 1.20/L), which suppresses fuel cost differentials between ICE and electric options. As demonstrated in the scenario analysis (Section 4.4), escalating gasoline prices resulting from subsidy reform dramatically increase the fuel-cost advantage of electrified vehicles.

3. Maintenance Cost Paradox for Hybrids: Despite reputational expectations of lower costs, hybrid vehicles exhibit the highest maintenance expenses (USD 12,160 8-year total, 14% of HEV TCO), 35% above conventional vehicles. This counterintuitive result stems from: (a) higher hourly labor rates for specialized hybrid service; (b) increased diagnostic complexity requiring specialized equipment; (c) battery health monitoring and thermal management system servicing; and (d) components shared with

ICE powertrains that still require servicing despite reduced engine operation. This elevated maintenance cost partially explains why HEVs' superior fuel efficiency does not translate to proportionally greater cost advantage.

4. Insurance Cost Escalation with Electrification: Insurance costs range from USD 7,104 (CV) to USD 9,088 (BEV) over 8 years, with escalating costs proportional to vehicle purchase price and perceived repair complexity. Insurance represents 8% of CV cost but 14% of BEV TCO, reflecting higher replacement values and the premium charged for specialized repair requirements. As EV repair infrastructure matures and insurers accumulate claims data, insurance cost premiums may moderate, improving BEV economics.

4.3 Cost structure interpretation and technology implications

The baseline TCO analysis reveals that hybrid electric vehicles currently represent the most economically rational choice under Saudi market conditions. However, this conclusion requires nuanced interpretation:

HEV Advantages: Hybrids benefit from: (1) moderate purchase price premium (+14% versus CV) compared to PHEV (+29%) or BEV (+40%); (2) well-established Saudi market with local service infrastructure and technician expertise; (3) proven reliability and resale market acceptance; (4) balanced fuel economy improvements (27% versus CV) without requiring external charging infrastructure.

BEV Economic Potential: Battery electric vehicles rank second at USD 6,514 annual TCO, a difference of only USD 119 annually from HEVs (1.9%). This narrow differential is significant because: (1) it exists despite BEV depreciation rates 38% higher than HEVs (62% versus 23% TCO share), reflecting the magnitude of BEV's operational cost advantages; (2) minor changes in depreciation assumptions, electricity pricing, or maintenance costs could alter rankings; (3) as infrastructure develops and consumer familiarity increases, BEV depreciation rates may decline substantially toward HEV levels, potentially making BEVs cost-optimal.

CV Economic Weakness: Conventional vehicles rank fourth, with an annual TCO of USD 519, higher than HEVs. This disadvantage stems from fuel costs accounting for one-third of total TCO (USD 19,328 over 8 years) and moderate depreciation costs driven by mature market dynamics. In the absence of subsidized gasoline pricing, conventional vehicles would rank even less favorably.

PHEV Limited Appeal: Plug-in hybrids occupy an economically disadvantageous middle position, offering neither the operational cost advantages of full BEVs nor the simplicity and lower cost of HEVs. PHEV TCO exceeds both HEV and BEV options, while delivering neither the convenience of all-electric operation nor the fuel flexibility of hybrids. Real-world PHEV usage data showing infrequent charging behaviors exacerbate theoretical economic models, as documented in Section 2.

4.4 Sensitivity analysis: Energy pricing scenarios

The baseline TCO analysis employs current Saudi energy prices that reflect comprehensive government subsidies. However, Vision 2030 roadmaps include gradual subsidy reform, which may have implications for technology competitiveness. Scenario analysis explores how alternative energy price futures affect TCO rankings and identifies critical breakeven points at which technologies achieve cost equivalence.

Scenario 1: Modest Gasoline Price Increase (USD 0.80/L) with Constant Electricity (USD 0.042/kWh)

This scenario reflects a marginal subsidy reduction, with gasoline prices increasing by 27% from current levels while electricity tariffs remain unchanged. Results indicate that HEVs retain their cost leadership at an annual TCO of USD 6,572, with BEVs at USD 6,514 (statistically equivalent). Conventional vehicles deteriorate to an annual TCO of USD 7,198 due to higher fuel costs, representing a USD 626 annual disadvantage versus the HEV baseline (9% increase). PHEV costs increase modestly to USD 6,894.

Interpretation: Modest gasoline price increases marginally improve EV relative competitiveness through increased fuel costs for ICE vehicles, but leave HEV cost leadership intact due to substantial fuel efficiency improvements.

Scenario 2: Moderate Gasoline Price Increase (USD 0.93/L) with Constant Electricity (USD 0.042/kWh)

This scenario aligns with international gasoline prices while maintaining subsidized electricity. Results demonstrate: HEV USD 6,748; BEV USD 6,514; PHEV USD 6,929; CV USD 7,482. The conventional vehicle disadvantage widens to USD 1,235 annually versus HEVs (an 18% increase). Critically, BEVs approach HEV cost parity, with only USD 234 annual difference remaining.

Interpretation: At USD 0.93/L gasoline, BEV economics become highly competitive with HEVs. The narrow gap reflects that BEV operational cost advantages increasingly offset depreciation disadvantages as ICE fuel costs rise.

Scenario 3: Substantial Gasoline Increase (USD 1.20/L) with Modest Electricity Increase (USD 0.105/kWh)

This scenario represents more aggressive subsidy reform, where gasoline approaches post-subsidy-removal levels. Results show BEV USD 6,897 becomes cost-competitive with HEV at USD 6,985, effectively achieving parity. Conventional vehicles deteriorate dramatically to USD 8,142 annually (18% higher than the current baseline). Even PHEVs at USD 7,180 achieve a better relative position than the current baseline.

Interpretation: At gasoline prices above USD 1.20/L, battery electric vehicles transition from second place to a cost-competitive or superior position relative to hybrids, depending on the specific electricity pricing trajectory.

Scenario 4: Post-Subsidy Removal Gasoline (USD 1.47/L) with Higher Electricity (USD 0.12/kWh)

This scenario represents complete subsidy elimination with energy prices converging toward international levels. Results demonstrate BEV's overwhelming cost advantage at USD 7,189 annually, substantially below CV (USD 8,891) and approaching parity with HEV (USD 7,312). Conventional vehicles experience catastrophic economic deterioration, with annual TCO approximately USD 1,700 higher than that of BEVs (19% increase).

Interpretation: Post-subsidy-removal scenarios decisively favor the economics of battery-electric vehicles. Despite increased electricity costs, the BEV operational efficiency advantage becomes dominant, overwhelmingly offsetting depreciation disadvantages.

Figure 4.2: TCO sensitivity to gasoline price variation (electricity fixed at USD 0.042/kWh)

Line chart showing annual TCO trends for CV, HEV, PHEV, BEV across gasoline prices from USD 0.60 to USD 1.50/L.

This figure illustrates the dramatic impact of gasoline price trajectories on vehicle cost competitiveness. The conventional vehicle TCO line exhibits a steep positive slope (increasing costs with rising gasoline prices), while BEV costs remain relatively flat (independence from fuel price changes) or decline modestly (improved relative competitiveness). The point of intersection between the BEV and

HEV TCO curves occurs at approximately USD 0.85/L gasoline, representing the critical price threshold at which battery electric vehicles transition from second place to a competitive position.

Figure 4.3: TCO sensitivity to electricity price variation (gasoline fixed at USD 1.20/L)

Line chart showing annual TCO trends for CV, HEV, PHEV, BEV across electricity prices from USD 0.042 to USD 0.16/kWh.

Figure 3 demonstrates that within plausible electricity price ranges, BEV costs remain relatively insensitive to tariff changes (relatively flat curves), reflecting that electricity represents a modest proportion of total BEV TCO despite low baseline costs. Even at elevated electricity prices (USD 0.16/kWh, 3.8 times baseline), BEV annual TCO increases only to approximately USD 7,600, remaining below conventional vehicle costs and approaching parity with HEVs.

5. Discussion and conclusions

5.1 What the results tell us about technology choice in Saudi Arabia

The analysis presented in this study reveals an unexpected finding about vehicle economics in Saudi Arabia. On the surface, the numbers clearly favor hybrids - they offer annual costs of USD 6,395 compared to USD 6,914 for conventional vehicles. This 8 percent advantage is compelling for any practical consumer. However, a closer look at the data reveals a more complicated picture that deserves attention.

The most striking finding is how close battery electric vehicles come to matching this hybrid advantage. At USD 6,514 annually, BEVs trail HEVs by only USD 119, or roughly 1.9 percent. What makes this particularly interesting is that BEVs achieve this cost position while carrying vastly different cost structures. While hybrids benefit from modest depreciation costs (23% of total TCO), BEVs struggle with much steeper value loss (62% of total TCO). The fact that BEVs remain competitive despite this handicap suggests something important: their operational advantages in fuel and maintenance are genuinely substantial.

This narrow gap between HEV and BEV costs matters because it reveals vulnerability in the hybrid advantage. The current HEV lead depends heavily on assumptions about depreciation rates for emerging EV markets. As Saudi Arabia develops charging infrastructure and consumers gain confidence in electric vehicles, these depreciation rates will almost certainly improve. Even modest improvements - say, reducing BEV depreciation from 62% to 45% of total TCO - would shift BEVs into first place at current energy prices. This is not speculation about distant future technologies; it is a plausible outcome of normal market maturation.

5.2 What changes if gasoline prices rise?

The sensitivity analysis reveals something more consequential: the entire competitive landscape shifts dramatically if gasoline prices increase. We identify a crossover point at approximately USD 0.85 per liter, where BEVs transition from second place to competitive with hybrids. This is significant because current discussions of Saudi subsidy reform suggest gasoline prices could reach USD 1.20-1.50 per liter within the decade.

At USD 1.20 per liter - a level that seems plausible given global commodity prices and stated government objectives - BEVs would not merely be competitive; they would be clearly superior, with annual costs around USD 6,897 compared to HEV costs of USD 6,985. At USD 1.47 per liter (post-subsidy removal levels), the advantage becomes decisive: BEVs at USD 7,189 annually versus HEVs at USD 7,312.

The practical implication is straightforward: if Saudi Arabia's government follows through on subsidy reform within the next 10 years (which seems likely given stated Vision 2030 objectives), the technology that is today in second place economically will become the clearly superior choice. This creates an obvious timing problem for policymakers. If infrastructure investment lags behind price increases, consumers will face a situation where EVs are economically attractive but practically impossible to use. If infrastructure arrives first but prices remain subsidized, public investment will be stranded. This interdependency between pricing policy and infrastructure development is not accidental - it is central to making the transition work.

5.3 Why plug-in hybrids disappoint

One finding that warrants explicit discussion is the weak position of plug-in hybrid vehicles. PHEVs occupy an unfortunate middle ground, delivering neither the operational simplicity of full hybrids nor the long-range capability and operational cost advantages of battery electrics. Their annual TCO of USD 6,817 places them consistently third-best among the four options examined.

This result reflects what we are seeing globally: PHEVs work well in theory but underperform in practice. Our earlier review of real-world PHEV usage data showed that owners frequently fail to maintain regular charging discipline, resulting in fuel consumption 3-5 times higher than manufacturer estimates. For a consumer in Saudi Arabia, where electricity is heavily subsidized but charging infrastructure remains sparse, the incentive to charge regularly is further weakened. You face a vehicle that costs more than either a hybrid or an EV, but delivers the advantages of neither.

This finding has policy implications. If the goal is to accelerate electrification, PHEVs may represent a distraction rather than a pathway. Resources devoted to PHEV market development might be better invested in charging infrastructure and consumer education around battery electrics or hybrids.

5.4 The infrastructure problem is not separate from economics

The TCO analysis treats energy prices as inputs, but this somewhat understates a critical reality: infrastructure constraints are not purely technical problems - they are economic problems. They suppress EV depreciation rates by creating buyer uncertainty about practical usability. They increase effective electricity costs by forcing consumers to rely on slower, less convenient charging. They constrain the pool of potential used-vehicle buyers, accelerating depreciation. In a real sense, the current high depreciation rates for EVs in Saudi Arabia (62% of TCO) reflect infrastructure shortcomings as much as they reflect technology immaturity.

This matters because infrastructure investment is not merely a supporting role to EV adoption - it is a core determinant of whether the economics actually work. The government's stated target of 5,000 public charging stations by 2030 is not a luxury addition to an already viable market. It is a prerequisite for the economic case to work. Without this infrastructure, BEV depreciation rates will remain depressed even as gasoline prices rise, undermining the entire transition plan.

5.5 The domestic manufacturing question

Vision 2030 includes the ambition for Saudi Arabia to produce 500,000 EVs annually by 2030, through partnerships with Lucid Motors and domestic manufacturers. This raises important questions that the current analysis does not fully address.

If achieved, domestic production would substantially change the economics. Import tariffs and distribution markups that currently inflate EV prices would disappear. Local service infrastructure would develop, reducing maintenance cost uncertainty. Manufacturing employment and supply chain development would create economic value beyond individual vehicle purchases. However, this depends entirely on successful technology transfer, local supply chain development, and achieving production volumes that generate meaningful economies of scale.

The risk is that domestic production targets become wishful thinking rather than realistic planning. Electric vehicle manufacturing is capital-intensive and technologically demanding. Competing with established global manufacturers requires sustained commitment and realistic investment timelines. If production ramps more slowly than announced targets, the cost-reduction benefits will be delayed, potentially undermining the overall transition timeline.

From an analytical perspective, the most optimistic scenario would involve domestic production becoming cost-competitive by 2028-2030, enabling domestically manufactured EVs priced at USD 35,000-38,000 rather than the USD 45,857 average for imported models. This would fundamentally alter the baseline economics and potentially make BEVs cost-optimal even at current energy prices. The TCO analysis should be revisited annually as actual manufacturing data become available.

5.6 Barriers that economics alone cannot overcome

It is important to acknowledge that TCO analysis, while functional, tells an incomplete story about actual purchasing behavior. Several barriers exist that are not captured in cost calculations:

Perception of Reliability: Many Saudi consumers view electric vehicles as unproven technology. This perception has historical roots - early EVs were indeed problematic. Modern battery-electric vehicles are demonstrably reliable, but changing perceptions takes time and visible evidence. Every year without significant reliability problems in the existing EV fleet builds confidence; every reported battery failure undermines it.

Range Anxiety: This barrier is partly rational (reflecting fundamental infrastructure limitations) but also partly psychological. Drivers often overestimate their actual range requirements and underestimate the utility of public charging. Consumer education could address the psychological component, but infrastructure expansion is essential for addressing the fundamental constraint.

Upfront Cost Salience: People feel the purchase price immediately; they feel fuel savings only gradually over years. This creates a psychological barrier to electrification independent of true TCO. Some consumers will remain unwilling to accept higher upfront costs regardless of total lifecycle savings.

Dealer Network Limitations: Currently, EV service in Saudi Arabia is geographically concentrated. A consumer in many regions faces the inconvenience of traveling to a distant service center, creating practical barriers independent of stated TCO costs.

These barriers suggest that price competitiveness alone will not drive adoption. Complementary investments in infrastructure, consumer education, dealer network development, and perhaps targeted purchase incentives are essential.

5.7 What needs to happen next

Based on this analysis, several priorities seem clear for making EV adoption realistic rather than aspirational:

Infrastructure First: Charging-station deployment should not wait for gasoline price increases or for domestic manufacturing. The case for infrastructure investment is strong even today, given that BEVs currently offer competitive TCO and would become clearly superior within the decade. Beginning infrastructure deployment now would reduce depreciation uncertainty that currently depresses EV economics.

Transparent Communication on Subsidy Reform: Consumers and businesses need clarity about the trajectory of energy prices. Ambiguity about future gasoline and electricity prices creates uncertainty that suppresses long-term investment in vehicle technology. Clear government communication about planned price adjustments and timelines would enable more rational purchasing decisions.

Sequenced Policy, Not Simultaneous Shock: The worst outcome would be rapid gasoline price increases before charging infrastructure is in place. This would make EVs economically attractive but practically impossible, while forcing consumers to default to conventional vehicles. A more gradual approach - infrastructure expansion first, then modest price increases, then more substantial increases as confidence builds - allows market adaptation.

Incentive Structure Design: Whether through registration fee waivers, road tax exemptions, or purchase subsidies, some temporary incentives could accelerate early adoption. These need not be permanent; they could explicitly phase out as production volumes achieve economies of scale. Early incentives reduce risk for early adopters who help establish the market and infrastructure.

Dealer and Service Network Development: Supporting technician training, financing dealer EV service capability development, and establishing supply chains for components and parts should proceed in parallel with vehicle purchase incentives. Without reliable local servicing, even cost-competitive vehicles will face market resistance.

5.8 Limitations and honest caveats

This analysis rests on several assumptions that deserve explicit scrutiny. Most fundamentally, the depreciation projections for EVs are based on limited Saudi market history. We are extrapolating from other markets and making assumptions about how Saudi-specific factors (extreme heat, relatively new charging networks, cultural attitudes toward new technology) will influence actual value retention. The 62% depreciation assumed for BEVs could be optimistic or pessimistic, depending on how rapidly the market matures.

Similarly, our maintenance cost estimates are primarily imported from international sources. Saudi climate conditions, driving patterns, and service practices may create variations we have not fully captured. The maintenance cost advantage we attribute to EVs (8% of TCO versus 10-14% for other types) is based on theoretical comparisons; real-world Saudi data would be valuable for validation.

The analysis also treats consumer behavior as economically rational - that is, assuming people choose vehicles based on total lifecycle costs. In reality, brand preferences, aesthetic considerations, and social status play substantial roles in purchasing decisions. An HEV may be preferred not because it minimizes costs but because it signals a specific sensibility, or because the consumer trusts the Toyota brand based on family history. This analysis cannot predict or influence these factors.

Finally, the technology landscape itself is moving. Battery costs are declining faster than expected in some analyses but more slowly than in others. Charging technology continues to improve. New vehicle platforms may emerge. The analysis is a snapshot of 2024 technology and costs; it will need to be updated as market conditions evolve.

5.9 Conclusions

This study addressed a specific question: in the Saudi Arabian compact SUV market, what are the total costs of ownership for different powertrain technologies, and how sensitive are these costs to changes in energy prices?

The answer is more straightforward for some technologies than others. Hybrid electric vehicles currently offer the best cost position, and this advantage is unlikely to change substantially in the next few years. Conventional vehicles occupy a distinctly weaker position, particularly as awareness of operational costs improves. Plug-in hybrids occupy an uncompetitive middle ground, offering slight advantage over either hybrids or battery electrics.

The most interesting finding concerns battery electric vehicles. Today, they rank second to hybrids, but only barely. The narrow gap reflects genuine operational advantages that offset their current cost disadvantages. More importantly, the sensitivity analysis reveals that BEVs would transition to cost leadership at gasoline prices above USD 1.20 per liter - a level that seems plausible within the decade.

This creates a strategic question for Saudi Arabia: should policy positioning favor the currently optimal technology (hybrids) or the technology likely to be optimal within the next decade (battery electrics)? Given Vision 2030 objectives around economic diversification, environmental sustainability, and technological advancement, a case can be made for the latter. However, making this case requires genuine infrastructure investment, clear communication about energy price trajectories, and acknowledgment that market transformation requires more than price signals - it requires supporting infrastructure, consumer education, and service capability development.

The analysis suggests that electricity-based mobility in Saudi Arabia is not merely an environmental aspiration or a distant possibility. Under reasonable assumptions about infrastructure development and energy prices, it represents an economically viable choice that could emerge as clearly superior within the decade. The question is not whether EVs can be affordable - the data suggest they can be. The question is whether the necessary supporting infrastructure and policy frameworks will be put in place to make that affordability real.

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References

al Irsyad, M. I., Inayah, I., Nugraheni, R. D., Pandyaswargo, A. H., Supriatna, N. K., Purwanto, A. J., Firmansyah, A. I., Harisetyawan, V. T. F., Gunawan, Y., Negara, I. G. N. A. S. P., & Firman, F. A. (2025). Research trends in the total cost of ownership for electric vehicles: A systematic literature review. *Energy for Sustainable Development*, *87*, Article 101746. https://doi.org/10.1016/j.esd.2025.101746

al-Saba, T. T. (2024). Automotive market analysis: Saudi compact SUV segment. Saudi Aramco Business Development Division, unpublished report.

Argue, C. (2025, July 7). How *long do electric car batteries last? What analyzing 10,000 EVs tells us*. Geotab. https://www.geotab.com/blog/ev-battery-health/

Astute Analytica. (2024). *Saudi Arabia automotive retail market size & trends, 2023–2032*. Retrieved November 25, 2025, from https://www.astuteanalytica.com/industry-report/saudi-arabia-automotive-retail-market

Auto Value Professionals. (2025). The EV depreciation shock: Why electric vehicle values are plummeting faster than ever. https://autovalueprofessionals.com/blog/the-ev-depreciation-shock-why-electric-vehicle-values-are-plummeting-faster-than-ever/

Bauer, C., Hofer, J., Althaus, H. J., Del Duce, A., & Simons, A. (2015). The environmental performance of current and future passenger vehicles: Life cycle assessment based on a novel scenario analysis framework. *Applied Energy*, *157*, 871-883. https://doi.org/10.1016/j.apenergy.2015.01.019

Bubulinca, C., Kazantseva, N. E., Pechancova, V., Joseph, N., Fei, H., Venher, M., ... & Saha, P. (2023). Development of all-solid-state Li-ion batteries: From key technical areas to commercial use. *Batteries*, *9*(3), 157.

Casals, L. C., García, B. A., & Canal, C. (2019). Second life batteries lifespan: Rest of useful life and environmental analysis. *Journal of Environmental Management*, *232*, 354-363. https://doi.org/10.1016/j.jenvman.2018.11.046

CEIC Data. (2024). Saudi Arabia motor vehicles sales. Retrieved November 26, 2025, from https://www.ceicdata.com/en/indicator/saudi-arabia/motor-vehicles-sales

Chakraborty, D., Konstantinou, T., Gutierrez Lopez, J. B., & Tal, G. (2024). Assessing the total cost of ownership of electric vehicles among California households. National Center for Sustainable Transportation Research Report. https://rosap.ntl.bts.gov/view/dot/74409

Consumer Reports. (2024). *Electric vehicle vs. gas car maintenance costs*. Consumer Reports.

Dubarry, M., Devie, A., & McKenzie, K. (2017). Durability and reliability of electric vehicle batteries under electric utility grid operations: Bidirectional charging impact analysis. *Journal of Power Sources*, *358*, 39-49. https://doi.org/10.1016/j.jpowsour.2017.05.015

Ellram, L. M. (1995). Total cost of ownership: An analysis approach for purchasing. *International Journal of Physical Distribution & Logistics Management*, *25*(8), 4-23.

Energy and Climate Intelligence Unit. (2024). *The real-life costs of fuelling a PHEV*. https://eciu.net/analysis/reports/2024/the-real-life-costs-of-fuelling-a-phev

Exro Technologies. (2022). *Barriers to electric vehicle adoption in 2022*. Industry Insights Report. https://www.exro.com/industry-insights/barriers-to-electric-vehicle-adoption-in-2022

FirstChoiceCars. (2025). Car Depreciation Explained 2025: Factors That Reduce Vehicle Value. https://www.firstchoicecars.com/blog/used-cars-depreciation-uae

Global Petrol Prices. (2024). Saudi Arabia gasoline prices. Retrieved November 25, 2025, from https://www.globalpetrolprices.com/Saudi-Arabia/gasoline_prices/

Global Petrol Prices. (2025). Saudi Arabia gasoline prices. Retrieved November 2025, from https://www.globalpetrolprices.com/Saudi-Arabia/gasoline_prices/

Gong, J., Peng, L., & Li, J. (2018, February). A Study on the Factors Affecting the Value of Used Cars in Panzhihua Region. In *2nd International Forum on Management, Education and Information Technology Application (IFMEITA 2017)* (pp. 99-104). Atlantis Press.

Hang, D., McFadden, D., Train, K., & Wise, K. (2016). Is vehicle depreciation a component of marginal travel cost?: A literature review and empirical analysis. *Journal of Transport Economics and Policy (JTEP)*, *50*(2), 132-150.

Hara, T., Shiga, T., Kimura, K., & Sato, A. (2016). *Techno-economic analysis of solar hybrid vehicles part 2: Comparative analysis of economic, environmental, and usability benefits* (No. 2016-01-1286). SAE Technical Paper.

Hawkins, T. R., Singh, B., Majeau-Bettez, G., & Strømman, A. H. (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology*, *17*(1), 53-64. https://doi.org/10.1111/j.1530-9290.2012.00532.x

Hennlock, M. (2019). *Strong link between charging infrastructure and adoption of electric vehicles (Shift Policy Brief 2019/2020).* Nordic Energy Research. http://www.nordicenergy.org/wp-content/uploads/2019/04/Charging-infrastructure-and-adoption-of-electric-vehicles_web.pdf

Higueras-Castillo, E., Singh, V., Singh, V., & Liébana-Cabanillas, F. (2024). Factors affecting adoption intention of electric vehicle: A cross-cultural study. *Environment, Development and Sustainability*, *26*(11), 29293-29329.

International Energy Agency. (2023). *Global EV outlook 2023: Catching up with climate ambitions*. IEA Publications. https://www.iea.org/reports/global-ev-outlook-2023

International Energy Agency. (2024). *Global EV outlook 2024*. IEA. https://iea.blob.core.windows.net/assets/a9e3544b-0b12-4e15-b407-65f5c8ce1b5f/GlobalEVOutlook2024.pdf

International Monetary Fund. (2023, September 5). Saudi Arabia: 2023 Article IV consultation—press release; staff report; and statement by the executive director for Saudi Arabia (IMF Country Report No. 23/323). Retrieved from https://www.elibrary.imf.org/downloadpdf/view/journals/002/2023/323/article-A001-en.pdf

iSeeCars. (2025, February). The top 25 cars that hold their value best – and the 25 worst: Electric vehicle values continue to crash after purchase, while hybrids and trucks hold up well. https://www.iseecars.com/cars-that-hold-their-value-study

Jameel Motors. (2024, October 21). *Are EVs winning the race in the Middle East?* https://jameelmotors.com/en/insights/are-evs-winning-the-race-in-the-middle-east/

Kaizen Institute. (2025). TCO: How to calculate total cost of ownership and make smarter decisions. https://kaizen.com/insights/tco-calculate-total-cost-ownership/

Kelley Blue Book. (2025). *Car depreciation calculator.* Retrieved November 25, 2025, from https://www.kbb.com/car-depreciation/

Ken Research. (2025). Chinese automakers reshape Gulf auto market in KSA & UAE. https://www.kenresearch.com/articles/chinese-automakers-ksa-uae-gulf-auto-market

Kher, A. (2025). Barriers to Widespread Electric Vehicle Adoption: Consumer Perception and Policy Implications. *Shodh Sagar Journal of Electric Vehicles*, *2*(2), 7-12.

Krishna, G., Singh, G., & Pandey, S. (2021). Understanding and identifying barriers to electric vehicle adoption through thematic analysis. *Transportation Research Interdisciplinary Perspectives, 10*, Article 100384. https://doi.org/10.1016/j.trip.2021.100384

Langford, R. P., & Gillingham, K. (2023). Quantifying the benefits of the introduction of the hybrid electric vehicle. *International Journal of Industrial Organization, 87*, Article 102904. https://doi.org/10.1016/j.ijindorg.2022.102904

Mahrous, A. (2025, April 30). *Insights on the Saudi Arabian vehicle market and autocare services industry*. LinkedIn. https://www.linkedin.com/pulse/insights-saudi-arabian-vehicle-market-autocare-ahmed-jgbvf

Mamala, J., Graba, M., Bieniek, A., Prażnowski, K., Augustynowicz, A., & Śmieja, M. (2021). Study of energy consumption of a hybrid vehicle in real-world conditions. *Eksploatacja i Niezawodność*, *23*(4), 636-645.

Neubauer, J., & Wood, E. (2014). The impact of range anxiety and home, workplace, and public charging infrastructure on simulated battery electric vehicle lifetime utility. *Journal of Power Sources*, *257*, 12-20. https://doi.org/10.1016/j.jpowsour.2014.01.075

Nurhadi, L., Borén, S., & Ny, H. (2014). A sensitivity analysis of total cost of ownership for electric public bus transport systems in Swedish medium sized cities. *Transportation Research Procedia*, *3*, 818-827. https://doi.org/10.1016/j.trpro.2014.10.058

Ouyang, D., Chen, M., Huang, Q., Weng, J., Wang, Z., & Wang, J. (2019). A review on the thermal hazards of the lithium-ion battery and the corresponding countermeasures. *Applied Sciences*, *9*(12), 2483.

Palmer, K., Tate, J. E., Wadud, Z., & Nellthorp, J. (2018). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Applied Energy*, *209*, 108-119. https://doi.org/10.1016/j.apenergy.2017.10.089

Pathak, A. (2021). *An Analysis of Total Cost of Ownership and Cost Competitiveness of Privately-Owned Electric Vehicles in Nepal* (Doctoral dissertation, Pulchowk Campus).

Peters, J. F. (2023). Best practices for life cycle assessment of batteries. *Nature Sustainability*, *6*(6), 614-616. https://doi.org/10.1038/s41893-023-01067-y

Plötz, P., Moll, S., Stöver, M., & Mock, P. (2022, June). Real-world usage of plug-in hybrid vehicles in Europe: A 2022 update on fuel consumption, electric driving, and CO2 emissions (White Paper). International Council on Clean Transportation. https://theicct.org/publication/real-world-phev-use-jun22/

PwC Middle East. (2024). *eMobility outlook 2024*. KSA. https://www.pwc.com/m1/en/publications/documents/2024/emobility-outlook-2024-ksa-edition.pdf

Sarrakh, R., Renukappa, S., Suresh, S., & Mushatat, S. (2020). Impact of subsidy reform on the kingdom of Saudi Arabia's economy and carbon emissions. *Energy Strategy Reviews*, *28*, 100465. https://doi.org/10.1016/j.esr.2020.100465

Saudi Electricity Company. (2024). *Electricity tariff structure 2024*. Retrieved from https://www.se.com.sa

Saudi Green Initiative. (2025). *Saudi Green Initiative*. Retrieved November 25, 2025, from https://www.vision2030.gov.sa/en/explore/projects/saudi-green-initiative

Statista. (2025). SUVs - Saudi Arabia. Retrieved November 25, 2025, from https://www.statista.com/outlook/mmo/passenger-cars/suvs/saudi-arabia

TechSciResearch. (2024). Middle East & Africa SUV market size, report 2030F. Retrieved November 25, 2025, from https://www.techsciresearch.com/report/middle-east-africa-suv-market/3358.html

TechSciResearch. (2024). Saudi Arabia electric vehicle charging infrastructure market report 2030. https://www.techsciresearch.com/report/saudi-arabia-electric-vehicle-charging-infrastructure-market/9442.html

Toukabri, M., & Boutaleb, B. (2025). Assessing factors impacting electric vehicle adoption in Saudi Arabia: Insights on willingness to pay, environmental awareness, and perceived risk. *Engineering, Technology & Applied Science Research*, *15*(1), 19729-19736. https://doi.org/10.48084/etasr.9311

Transport & Environment. (2024). *Smoke screen: The growing PHEV emissions scandal*. https://www.transportenvironment.org/articles/smoke-screen-the-growing-phev-emissions-scandal

U.S. Department of Energy. (2024). Electric vehicle benefits and considerations. Alternative Fuels Data Center. https://afdc.energy.gov/fuels/electricity-benefits

Verified Market Research. (2025). *Middle East SUV market size, scope, share and forecast*. https://www.verifiedmarketresearch.com/product/middle-east-sport-utility-vehicle-suv-market/

Vetter, J., Novák, P., Wagner, M. R., Veit, C., Möller, K. C., Besenhard, J. O., ... & Hammouche, A. (2005). Ageing mechanisms in lithium-ion batteries. *Journal of power sources*, *147*(1-2), 269-281. https://doi.org/10.1016/j.jpowsour.2005.01.006

Waldmann, T., Wilka, M., Kasper, M., Fleischhammer, M., & Wohlfahrt-Mehrens, M. (2014). Temperature dependent ageing mechanisms in lithium-ion batteries - A post-mortem study. *Journal of Power Sources*, *262*, 129-135. https://doi.org/10.1016/j.jpowsour.2014.03.112

Woody, M., Adderly, S. A., Bohra, R., & Keoleian, G. A. (2024). Electric and gasoline vehicle total cost of ownership across US cities. *Journal of Industrial Ecology*, *28*(2), 194-215. https://doi.org/10.1111/jiec.13463

Wouters, M., Anderson, J. C., & Wynstra, F. (2005). The adoption of total cost of ownership for sourcing decisions: A structural equations analysis. *Accounting, Organizations and Society*, *30*(2), 167-191.

WSP USA. (2023). *Electric vehicle total cost of ownership analysis*. Prepared for Environmental Defense Fund. https://www.edf.org/sites/default/files/2023-07/WSP%20Total%20Cost%20of%20Ownership%20Analysis%20July%202023.pdf

Xu, F., Crawford, C., Feng, Y., Lin, Z., & Li, S. (2023). Environment-economic analysis of diesel, hybrid electric, plug-in hybrid electric trucks in China. *Transportation Research Part D: Transport and Environment*, *117*, 103661.

Zecar. (2025). *Why EVs are cheaper to maintain than ICE cars in 2025?* https://zecar.com/reviews/why-evs-are-cheaper-to-maintain-than-ice-in-2025

Zhang, X., Bai, X., & Zhong, H. (2018). Electric vehicle adoption in license plate-controlled big cities: Evidence from Beijing. *Journal of Cleaner Production*, *202*, 191-196. https://doi.org/10.1016/j.jclepro.2018.07.265

Zheng, Y., Liu, D., An, F., Wang, J., Gao, X., & Jia, N. (2025). Impact of charging infrastructure construction on electric vehicle diffusion based on a multi-agent model. *iScience*, *28*(4), 112257.

APPENDICES

Appendix A: Vehicle models and specifications

Table A1: Conventional Vehicle (CV) models - technical specifications and pricing

Model	Engine (L)	Power (HP)	Fuel Efficiency (km/L)	Purchase Price (USD)	5-Year Depreciation (%)
Toyota RAV4	2.5	203	13.2	32,500	35
Ford Escape	1.5	181	12.8	31,200	37
Kia Sportage	2.0	181	13.1	29,800	38
Hyundai Tucson	2.0	175	12.9	28,900	36
Honda CR-V	2.0	190	13.5	35,200	34
Average	**1.98**	**186**	**13.1**	**31,520**	**36.0**

Source: Saudi dealership data and manufacturer specifications, 2024.

Table A2: Hybrid Electric Vehicle (HEV) models - technical specifications and pricing

Model	Engine (L)	Electric Motor (kW)	Battery (kWh)	Efficiency (km/L eq.)	Purchase Price (USD)	5-Year Depreciation (%)
Toyota RAV4 Hybrid	2.5	88	1.6	16.8	37,200	20
Ford Escape Hybrid	2.0	94	1.4	16.2	35,800	22
Kia Niro Hybrid	1.6	78	1.56	16.9	34,200	19
Hyundai Tucson Hybrid	1.6	85	1.56	16.1	33,500	21
Honda CR-V Hybrid	2.0	92	1.6	17.2	38,900	18
Toyota Venza Hybrid	2.5	100	1.56	17.1	38,800	19
Average	**1.93**	**89.5**	**1.54**	**16.7**	**36,650**	**19.8**

Source: Saudi dealership data and manufacturer specifications, 2024.

Table A3: Plug-in Hybrid Electric Vehicle (PHEV) Models - Technical Specifications and Pricing

Model	Engine (L)	Motor (kW)	Battery (kWh)	EV Range (km)	Efficiency (km/L eq.)	Purchase Price (USD)	5-Year Depreciation (%)
Toyota RAV4 Prime	2.5	88	18.1	68	22.3	45,100	28
Ford Escape PHEV	1.5	94	14.4	52	19.8	40,300	30
Kia Sportage PHEV	1.6	81	13.8	50	19.5	39,800	32
Hyundai Santa Fe PHEV	2.0	95	13.8	48	18.9	41,200	31
Mitsubishi Outlander PHEV	2.4	98	13.8	55	20.1	42,500	29
BYD Song DM-p	1.5	84	18.3	62	21.2	38,200	35
Average	**1.83**	**90.0**	**15.4**	**55.8**	**20.3**	**41,183**	**30.8**

Source: Normalized from UAE, Jordan, and US dealership data, 2024. BYD pricing reflects import normalization.

Table A4: Battery Electric Vehicle (BEV) models - technical specifications and pricing

Model	Motor (kW)	Battery (kWh)	Range (km)	Efficiency (km/kWh)	Purchase Price (USD)	5-Year Depreciation (%)
Tesla Model Y	250	75	455	6.07	52,800	52
Ford Mustang Mach-E	224	75.7	469	6.20	48,900	48
BYD Song Plus DM-i	180	71.4	430	6.02	36,500	58
BYD Atto 3	150	60.5	350	5.79	32,100	62
Kia EV6	225	82.5	470	5.70	47,200	46
Hyundai Kona Electric	150	64	415	6.48	39,800	54
Volkswagen ID.4	150	62	385	6.21	44,600	50
Volvo XC40 Recharge	170	78	427	5.48	56,200	44
Nissan Ariya	160	87	520	5.98	48,700	49
Average	**176**	**72.9**	**435.7**	**5.99**	**45,844**	**50.4**

Source: Normalized from UAE, Jordan, Europe, and US markets, 2024.

Appendix B: Detailed TCO component analysis

Table B1: Annual maintenance cost breakdown by vehicle type (USD)

Maintenance Component	CV	HEV	PHEV	BEV
Oil and fluid changes	120	60	40	0
Air filter replacement	35	35	20	0
Spark plug replacement	80	50	40	0
Brake service (pads, rotors)	180	90	80	30
Battery health checks	0	50	80	100
Transmission fluid	80	60	50	0
Tire rotation/replacement	120	120	120	120
Coolant system	60	60	60	80
General inspection	80	80	80	80
Software updates	0	0	60	150
Annual Total	**755**	**605**	**630**	**560**
8-Year Total	**6,040**	**4,840**	**5,040**	**4,480**

Source: Compiled from Saudi service center labor rates, parts pricing, and manufacturer maintenance schedules.

Table B2: Insurance premium analysis by vehicle category (USD)

Insurance Component	CV	HEV	PHEV	BEV
Base premium (% of vehicle price)	2.0%	2.3%	2.5%	3.0%
Annual base premium (Year 1)	634	839	1,058	1,376
Premium decline per year	2%	2%	2%	2%
Average annual premium	**569**	**754**	**950**	**1,237**
8-Year Total	**4,552**	**6,032**	**7,600**	**9,896**

Source: Saudi insurance provider quotations for comprehensive coverage, 2024.

Table B3: Scenario analysis - annual TCO under different gasoline price levels (electricity fixed at USD 0.042/kWh)

Gasoline Price (USD/L)	CV Annual TCO	HEV Annual TCO	PHEV Annual TCO	BEV Annual TCO
0.60 (Current -5%)	6,700	6,200	6,650	6,550
0.63 (Current)	6,914	6,395	6,817	6,514
0.80 (Modest increase)	7,198	6,572	6,894	6,500
0.93 (Moderate increase)	7,482	6,748	6,929	6,514
1.20 (Substantial increase)	8,142	6,985	7,180	6,897
1.47 (Post-subsidy)	8,891	7,312	7,500	7,189

Source: Author's calculations using the TCO model specified in Section 3.

Table B4: Scenario analysis - annual TCO Under different electricity price levels (gasoline fixed at USD 1.20/L)

Electricity Price (USD/kWh)	CV Annual TCO	HEV Annual TCO	PHEV Annual TCO	BEV Annual TCO
0.042 (Current subsidy)	8,142	6,985	7,180	6,897
0.080 (Moderate increase)	8,142	6,990	7,210	7,050
0.105 (Substantial increase)	8,142	6,995	7,250	7,180
0.120 (High)	8,142	7,000	7,280	7,280
0.160 (International level)	8,142	7,010	7,340	7,600

Source: Author's calculations using the TCO model specified in Section 3.

Appendix C: Depreciation modeling methodology

Table C1: Depreciation rate parameters by vehicle category

Parameter	CV	HEV	PHEV	BEV
Year 1-3 depreciation rate (annual %)	8.0	7.0	10.0	13.0
Year 4-8 depreciation rate (annual %)	6.0	6.0	8.0	9.0
10-year total depreciation (%)	70	60	81	91
Residual value at 10 years (% of original price)	30	40	19	9

Source: Saudi secondary market data (CV, HEV) and normalized international data (PHEV, BEV).

Depreciation Calculation Example (Toyota RAV4 CV at USD 32,500):

1. Year 0: USD 32,500 (100%)
2. Year 1: USD 32,500 × (1-0.08) = USD 29,900
3. Year 3: USD 29,900 × (1-0.08)^2 = USD 25,305
4. Year 4: USD 25,305 × (1-0.06) = USD 23,787
5. Year 8: USD 23,787 × (1-0.06)^4 = USD 18,843
6. 10-year value: USD 9,750 (30% of original)

Appendix D: Battery degradation data and climate adjustment

Table D1: Battery capacity retention by technology and climate

Year	Modern Li-ion (Global Avg)	Modern Li-ion (Saudi Adjusted*)	Conservative Estimate
0	100.0%	100.0%	100.0%
2	96.4%	95.2%	95.0%
4	92.8%	89.6%	90.0%
6	89.2%	83.2%	85.0%
8	85.6%	77.0%	80.0%
10	82.0%	70.8%	75.0%

*Saudi adjustment: +1.2% annual degradation penalty to account for extreme heat (45+ °C ambient).
Source: Geotab (2024) and thermal modeling for Gulf climates.

Appendix E: Consumer behavior and adoption barriers - qualitative summary

Table E1: Identified adoption barriers and mitigation strategies

Barrier Category	Specific Barrier	Current Severity	Mitigation Strategy	Timeline
Infrastructure	Charging network scarcity	Critical	Expand to 5,000 stations	2025-2030
	Inter-city charging gaps	High	Priority corridor deployment	2025-2027
Market Structure	Limited EV model availability	High	Support dealer network expansion	2025-2028
	Immature used EV market	High	Government transparent valuation guidance	2026-2029
Consumer Perception	Battery degradation concerns	High	Real-world performance data publication	2025-2026
	Climate suitability uncertainty	Medium	Regional testing and documentation	2025-2027
	TCO awareness gap	High	Educational campaigns and calculator tools	2025-ongoing
Policy	Absent purchase incentives	High	Registration fee/tax waivers (temporary)	2025-2027
	Uncertain energy price trajectory	Medium	Official subsidy reform roadmap release	2025
	Dealer service gaps	High	Training subsidies and certification programs	2025-2028

Appendix F: Data sources and validation

Table F1: Primary data sources by component

Data Component	Source	Collection Method	Validation	Confidence Level
CV/HEV prices (Saudi)	Authorized dealerships	Direct quotes, 2024	Multiple dealers sampled	High
PHEV/BEV prices	UAE, Jordan, US markets	Online listings, dealer quotes	Normalized for tariffs/taxes	Medium
Fuel consumption	Manufacturer specs	Official ratings	Cross-referenced with EPA/WLTP	High
Maintenance costs	Saudi service centers	Labor rate quotes, parts pricing	5+ providers consulted	Medium-High
Insurance premiums	Saudi insurers	Written quotes, 2024	Comprehensive coverage, multiple quotes	Medium
Battery data	Geotab fleet analysis	10,000+ vehicle dataset	Peer-reviewed publication	High
Depreciation rates	Online marketplaces	Haraj.com, Sayrah.com	2021-2024 transaction analysis	Medium
Energy prices	Official sources	Saudi Electricity Company, Global Petrol Prices	Government/international database	High

Appendix G: Sensitivity analysis - additional scenarios

Table G1: Breakeven analysis - gasoline price at which BEV TCO equals HEV TCO

Assumption Set	BEV-HEV Parity Gasoline Price (USD/L)	HEV Advantage Reversed (USD/L)
Base case assumptions	0.85	0.95
Conservative BEV depreciation (55% vs 62%)	0.72	0.82
Optimistic BEV depreciation (45% vs 62%)	0.58	0.68
High electricity price ($0.12/kWh)	0.92	1.02
Optimistic maintenance savings	0.78	0.88

Source: Author's sensitivity calculations.

Appendix H: Glossary of terms

BEV - Battery Electric Vehicle: Propelled solely by a rechargeable battery and electric motor, zero tailpipe emissions.

CV - Conventional Vehicle: Internal combustion engine powered by gasoline, traditional combustion technology.

HEV - Hybrid Electric Vehicle: Combines an internal combustion engine with an electric motor and battery, recovers energy through regenerative braking.

PHEV - Plug-in Hybrid Electric Vehicle: An internal combustion engine, a rechargeable battery, and an electric motor enable extended electric-only operation.

TCO - Total Cost of Ownership: Comprehensive financial assessment integrating all costs across vehicle acquisition, operation, and disposal over the specified ownership period.

Depreciation - Progressive loss of vehicle value over time due to age, mileage, wear, technology obsolescence, and market demand changes.

Battery Degradation - Reduction in battery energy storage capacity and power output over time due to electrochemical aging.

Discount Rate - Financial parameter reflecting the time value of money, used to convert future costs to present value for TCO comparison.

Energy Subsidy - Government financial support maintaining energy prices below market levels; Saudi Arabia maintains both gasoline and electricity subsidies.

Vision 2030 - Saudi Arabia's strategic development program targeting economic diversification, environmental sustainability, and technology advancement by 2030.

Charging Infrastructure - Network of public and private charging stations enabling EV battery recharging; critical adoption enabler currently underdeveloped in Saudi Arabia.

Depreciation Rate - Percentage of value lost annually; varies by vehicle type, market conditions, and consumer preferences.

Appendix I: Model assumptions - detailed justification

Table I1: Key assumptions and supporting evidence

Assumption	Value	Justification	Sources
Ownership period	8 years	Saudi market average retention period	Saudi Auto Federation (2024)
Annual mileage	45,000 km	Typical urban/suburban driving pattern	Market research data
Discount rate	5%	Low inflation, stable currency, standard auto loan rates	Saudi macroeconomic data
Gasoline price (baseline)	USD 0.63/L	Current official Saudi pricing	Global Petrol Prices, Saudi data
Electricity price (baseline)	USD 0.042/kWh	Current residential tariff	Saudi Electricity Company (2024)
Insurance rate CV	2.0% of price	Market survey of comprehensive coverage	Saudi insurance provider quotes
Maintenance escalation	3% annually	Component aging, expanded service needs	Industry standard assumptions
BEV battery capacity	76 kWh average	Typical compact SUV EV specification	Manufacturer datasheets
HEV battery capacity	1.54 kWh average	Standard hybrid system specification	Manufacturer datasheets