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MAPPING THE EV ECOSYSTEM IN PAKISTAN

FROM POLICY TO MARKET ADOPTION

Authors: M. Sarim Zia | Ms. Saleha Qureshi | Engr. Ubaid ur Rehman Zia | Dr. Khalid Waleed

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MAPPING THE **EV ECOSYSTEM** IN PAKISTAN

FROM POLICY TO MARKET ADOPTION

Greening of Highways in Pakistan

AUTHORS:
M. Sarim Zia | Ms. Saleha Qureshi | Engr. Ubaid ur Rehman Zia | Dr. Khalid Waleed

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Abbreviations and Acronyms

MoF	Ministry of Finance
SBP	State Bank of Pakistan
MoIP	Ministry of Industries and Production
MoE	Ministry of Energy
MoST	Ministry of Science and Technology
FBR	Federal Board of Revenue
NEPRA	National Electric Power Regulatory Authority
DISCOs	Distribution Companies
MoPDSI	Ministry of Planning, Development, and Special Initiatives
CDA	Capital Development Authority
SEZA	Special Economic Zones Authority
BoI	Board of Investment
EDB	Engineering Development Board
HEC	Higher Education Commission
EV	Electric Vehicle
ICE	Internal Combustion Engine
GHG	Greenhouse Gas
NDC	Nationally Determined Contributions
KII	Key Informant Interview
FGD	Focus Group Discussion
PKR	Pakistani Rupee
USD	United States Dollar
CBU	Completely Built-Up
CKD	Completely Knocked Down
HEV	Hybrid Electric Vehicle
R&D	Research and Development
NEVP	National Electric Vehicle Policy
NEECA	National Energy Efficiency and Conservation Authority
PSQCA	Pakistan Standards and Quality Control Authority
PPP	Public-Private Partnership
BESS	Battery Energy Storage System
DG	Distributed Generation
P2V	Power-to-Vehicle
NPV	Net Present Value
ADB	Asian Development Bank
GCF	Green Climate Fund
CAPEX	Capital Expenditure
O&M	Operations and Maintenance
CPO	Charge Point Operator
TOU	Time of Use

EXECUTIVE SUMMARY

Pakistan's transport sector, predominately depend on internal combustion engine (ICE) vehicles, is grappling with intensifying environmental and economic pressure. The sector consumes over 40% of the country's total oil supply and contributes significantly to air pollution and climate change. Recent analysis reveals that transport alone accounts for 79.29% of national oil consumption, far exceeding other sectors, such as industry (6.45%), overseas transport (8.51%), and power generation (3.64%). This overreliance on imported fossil fuels places a substantial burden on Pakistan's foreign exchange reserves and intensifies the risks of energy insecurity and environmental degradation.

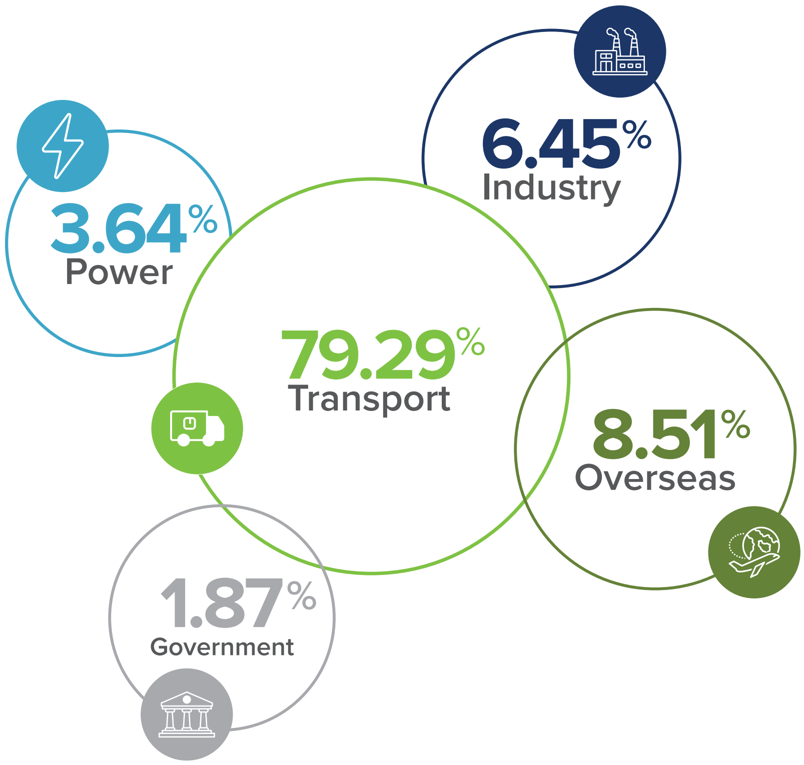


Figure 1: Sectoral Share of Oil Consumption in Pakistan (Source: Pakistan Economic Survey 2024-25)

Besides its oil dependence, the transport sector is also one of the leading sources of greenhouse gas (GHG) emissions. It contributes approximately 24% of total national GHG emissions, ranking just behind manufacturing and construction (35%), and ahead of energy industries (23%) and other sectors (18%). The above Figure1 underscore the urgent need to decarbonize transport as a central pillar of Pakistan's climate strategy.

To address these twin challenges of oil dependence and climate vulnerability, the Government of Pakistan has committed under its Nationally Determined Contributions (NDCs) to ensure that 30% of all new vehicle sales are electric by 2030 and that road transport achieves full decarbonization by 2060. However, despite this policy ambition, EV adoption in Pakistan remains nascent, constrained by high upfront costs, limited access to financing, weak charging infrastructure, and lack of consumer awareness. These barriers are especially acute in the mass market for two- and three-wheelers, which represent more than 90% of the national vehicle fleet and serve as the backbone of daily mobility for millions of low-income and informal sector users.

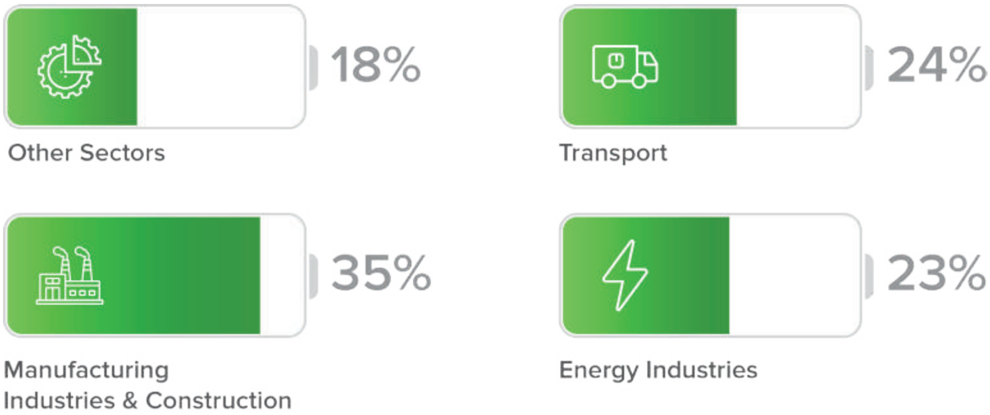
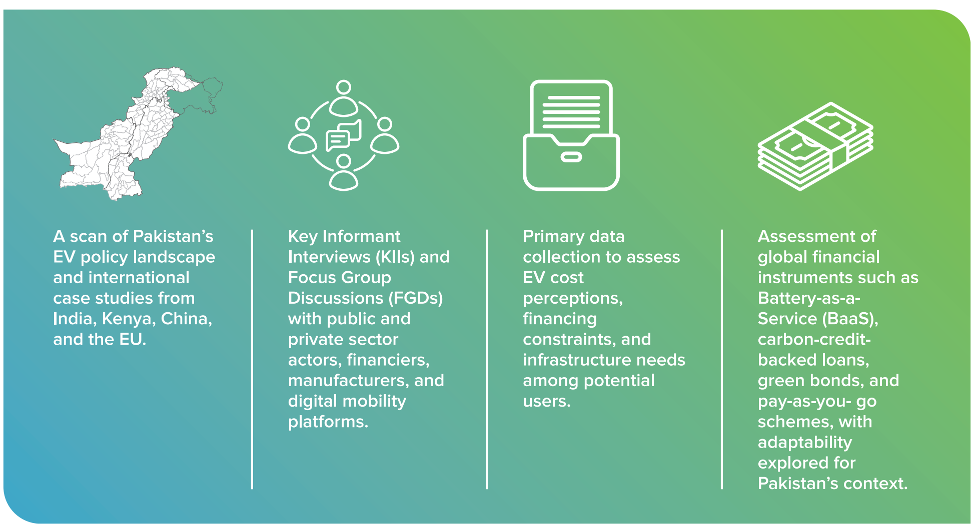


Figure 2: *Sectoral Share of GHG Emissions in Pakistan*

This study investigates the financial and structural barriers to EV adoption in Pakistan, with a focus on the scalable deployment of electric two- and three-wheelers. Furthermore, the research methodology integrates both qualitative and quantitative tools, including key informant interviews (KIIs), focus group discussions (FGDs), policy reviews, and consumer affordability surveys to conduct an analysis. The analysis is further grounded in cost-benefit assessments and behavioral modeling to determine feasible investment pathways and retirement timelines for ICE vehicles.



Despite long-term savings on fuel and maintenance, EVs in Pakistan—especially cars—cost 30 to 64% more upfront than equivalent ICE vehicles. This cost premium is largely driven by battery prices, which account for nearly 50% of the total vehicle cost. For the two- and three-wheeler segment, which has seen localized production by over 60 manufacturers, the lack of domestic battery manufacturing and reliance on imported components remain major constraints.

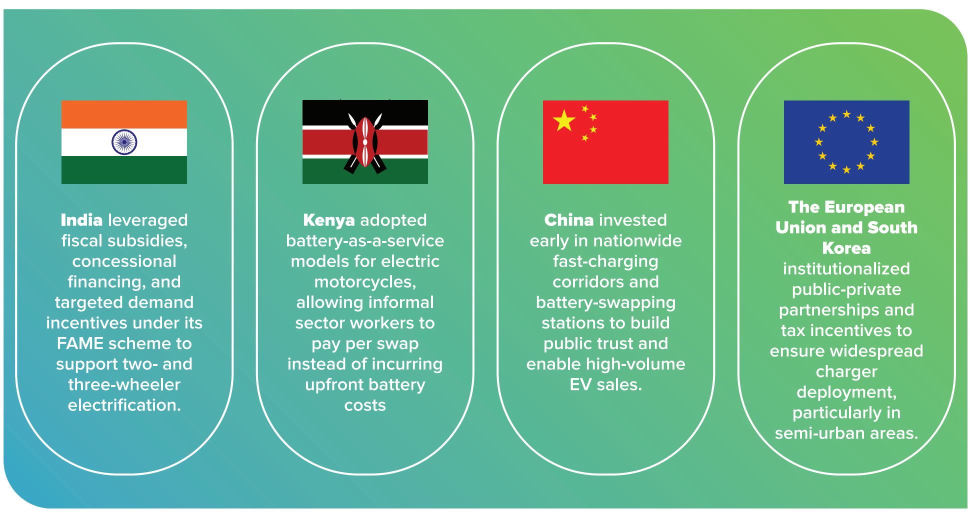
Access to financing is another critical bottleneck. Low-income consumers, who dominate the market for motorbikes and rickshaws, lack of credit histories and collateral, making them ineligible for traditional loans. While a few commercial banks have introduced pilot EV financing schemes, uptake remains low because of high interest rates and limited consumer education.

Pakistan's EV charging ecosystem is also trapped in a demand-supply deadlock. Limited public and private investment in charging infrastructure has resulted in low charger availability, particularly outside urban centres This, discourages EV adoption, creating a vicious cycle. Grid instability, urban land constraints, and the absence of national charging standards further inhibit growth.

While two- and three-wheeler assembly is underway, EV cars and battery elements are still not manufactured locally. A transition to a Completely Knocked Down (CKD) assembly model and the promotion of localized battery production are essential to reduce costs and enhance market competitiveness. Without implementing these changes, Pakistan will persist in its vulnerability to supply chain volatility and currency fluctuations, jeopardizing economic resilience.

One major opportunity lies in solar and wind-based Distributed Generation (DG) integrated with Battery Energy Storage Systems (BESS). These technologies can ensure reliable off-grid charging options in urban areas with poor grid access. The comparative analysis indicates that solar plus battery hybrid charging stations offer the best long-term returns, with zero operational energy costs and resilience against grid outages. Over 25 years, such models outperform grid-only and diesel-based systems in terms of environmental and financial sustainability.

This report highlights several international models that can be adapted to Pakistan's unique context:



If properly enabled through policy reform, financial innovation, and infrastructure investment, Pakistan's EV transition could deliver profound benefits. The country could save up to USD 2 billion annually in oil import costs, reduce carbon emissions by 53 million tons of CO_2, and generate more than PKR 109.6 billion annually in economic value through job creation, reduced health costs, and energy efficiency gains. This report concludes that electric mobility is not merely an environmental necessity; it is a strategic development opportunity. Pakistan has the potential to create a bankable, inclusive, and resilient EV ecosystem that advances affordability, equity, and climate resilience across all segments of society.

INTRODUCTION & PURPOSE

1.1
INTRODUCTION

The global transition towards electric vehicles (EVs) marks a significant shift in the transportation sector, driven by the need for sustainable mobility solutions, environmental conservation, and energy efficiency. Electric cars have become more popular recently because of better technology, government support, and climate change concerns. BloombergNEF (2024), projects that global EV sales will reach 17 million units by the end of the year, accounting for nearly one in every five cars sold worldwide. Countries across the globe are implementing multi-dimensional strategies to promote EVs, aiming to curb carbon emissions, reduce dependence on fossil fuels, and build resilient, low-emission transport systems.

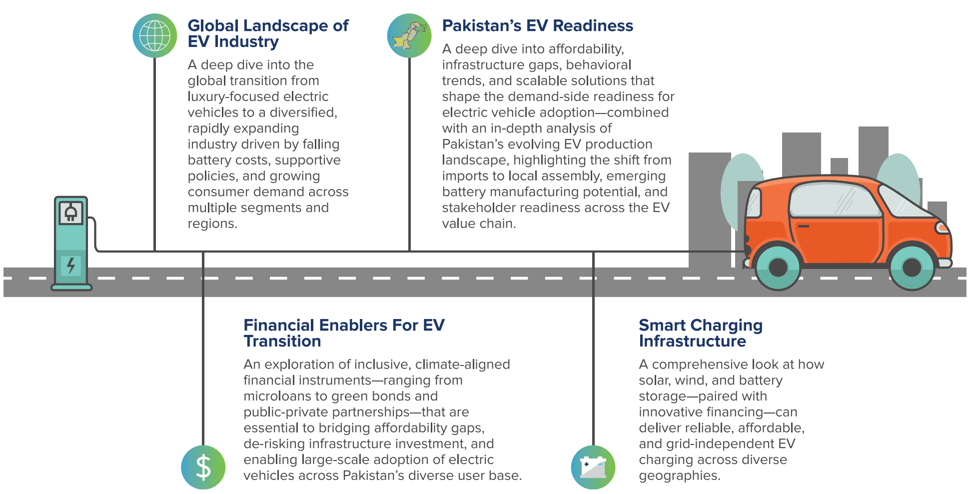
Figure 3: *Pakistan NEV Policy Landscape*

This transition is particularly critical for emerging economies like Pakistan, where energy security, urban air pollution, and economic vulnerability to oil price shocks are key national concerns. The transportation sector in Pakistan accounts for over 40% of the total oil consumption, making it a significant contributor to urban smog and greenhouse gas emissions. Notably, during the initial two months of FY2024–25 (July–August), the country's oil import bill surged by 23% year-on-year, reaching USD 2.53 billion, up from USD 2.06 billion in the corresponding year of the previous year (Profit, 2024). Meanwhile, air quality in major cities continues to deteriorate—Lahore recorded Air Quality Index (AQI) levels exceeding 1,100 in November 2024, far above the hazardous threshold of 300 (AP News, 2024). These alarming trends underscore the urgency of transitioning to electric mobility as a strategic economic and environmental priority.

Pakistan's automotive sector is undergoing a gradual transformation, with increasing interest in EVs as a potential solution to the country's fuel import burden and deteriorating air quality. The launch of National Electric Vehicle Policy (NEVP) in 2019 marked a pivotal step towards sustainable mobility, offering tax incentives, duty reductions, and plans to localize EV manufacturing. Building on this progress, the New Energy Vehicle (NEV) Policy aims to achieve a clear target of 30% EV in new vehicle sales by 2030, aligned with the broader aim of achieving a zero-emission road transport fleet by 2060 (Ministry of Industries and Production, 2025).

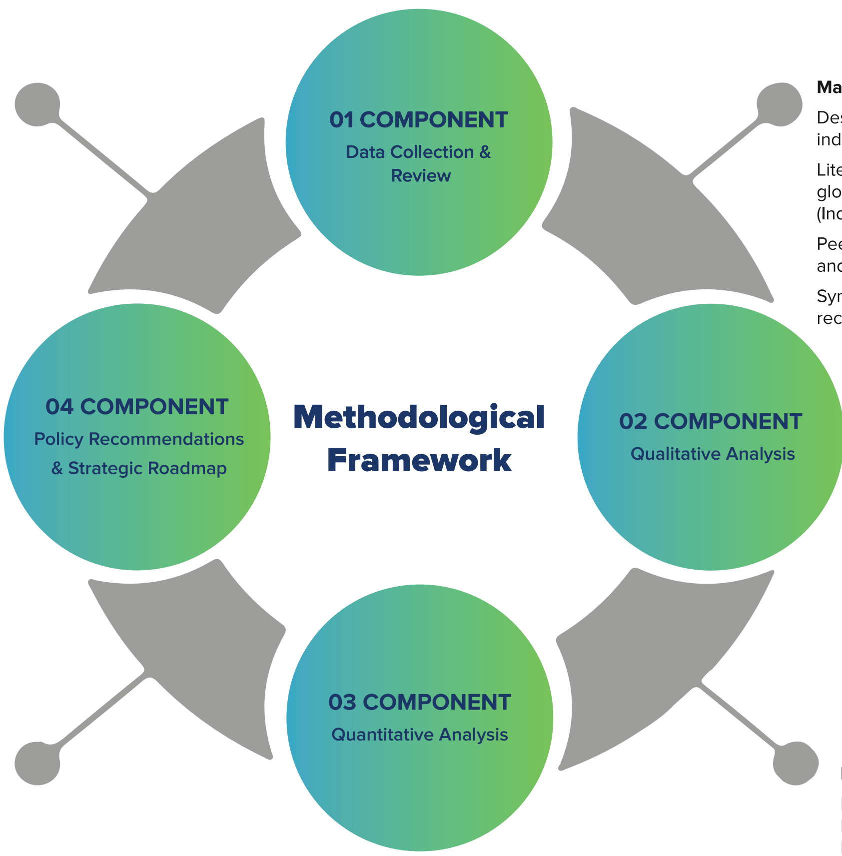
1.2. SCOPE

The report places particular emphasis on the role of two- and three-wheelers, which constitute a significant share of the national vehicle fleet. The analysis comprehensively reviews existing policy frameworks, identifies key barriers, such as infrastructure gaps and affordability constraints, and examines emerging solutions, such as battery-swapping models and solar-powered charging infrastructure. This report uses globally acknowledged methods to give a complete picture of how Pakistan's electric vehicle system is developing, and it suggests ways to help move towards a transport system that is both sustainable and can recover from problems.



1.3. METHODOLOGY

This report adopts a mixed-methods approach, combining both qualitative and quantitative techniques to evaluate Pakistan's transition towards electric mobility. Additionally, it employs a cost-benefit analysis framework alongside a comprehensive assessment of consumer perceptions related to electric vehicle (EV) adoption and the phase-out of internal combustion engine (ICE) vehicles.



01 COMPONENT — Data Collection & Review

Main outputs:

- Desk review of EV industry
- Literature review of global case studies (India, China, Kenya, EU)
- Peer-reviewed articles and industry publications
- Synthesis for recommendations

02 COMPONENT — Qualitative Analysis

Main outputs:

- Focus Group Discussions (FGDs) with EV manufacturers, banks, and ecosystem stakeholders
- Policy landscape review and analysis of NEVP (2019)
- Sector strategy insights and institutional mandates

03 COMPONENT — Quantitative Analysis

Main outputs:

- Cost comparison and Total Cost of Ownership (TCO) modeling
- Segment-wise EV vs. ICE price comparisons using PakWheels and dealership listings

04 COMPONENT — Policy Recommendations & Strategic Roadmap

Main outputs:

- Evidence-based roadmap for EV adoption in Pakistan
- Focus on low-cost, high-impact implementation areas
- Triangulation of qualitative and quantitative insights
- Transferable practices in EV financing, battery tech, and policy sequencing

SECTION I:
GLOBAL LANDSCAPE OF EV INDUSTRY

2.1. TRANSITION OF EVS: DEVELOPMENT FROM HIGH-END NICHE TO MAINSTREAM MOBILITY

The evolution of electric vehicles (EVs) in developed markets began with a focus on luxury, targeting affluent consumers motivated by technological enthusiasm, environmental consciousness, and the desire to be associated with a prestigious or premium brand. Early EVs were high-end models because of the significant cost of battery production and limited manufacturing expertise. The launch of the Tesla Roadster in 2008 exemplified this phase, delivering impressive performance and range, but at a premium price that restricted adoption to a niche market (Smart Electric Power Alliance, 2024; Rabobank, 2024).

During this initial wave, several automakers, such as BMW, Audi, and General Motors, introduced electric sedans and SUVs that prioritized performance and design over affordability. However, widespread adoption was hindered by critical barriers: battery prices exceeded $700 per kilowatt-hour in 2013 (BloombergNEF, 2023), charging infrastructure was sparse, and consumers were uncertain about battery lifespan. These factors, combined with a fragmented global supply chain, limited the scalability of EV production and kept the market largely restricted to high-income buyers across North America, Europe, and East Asia (McKinsey & Company, 2024; International Energy Agency, 2024).

By 2023, China had established itself as a dominant force in EV supply chains, accounting for nearly 90% of cathode and 97% of anode material production globally. This concentration of production capacity underlined a growing global dependence on Chinese manufacturing for EV components. While innovation in design and performance advanced significantly during this period, the combination of high costs, limited infrastructure, and supply chain constraints kept EVs positioned as premium products rather than accessible transportation solutions (International Energy Agency, 2024).

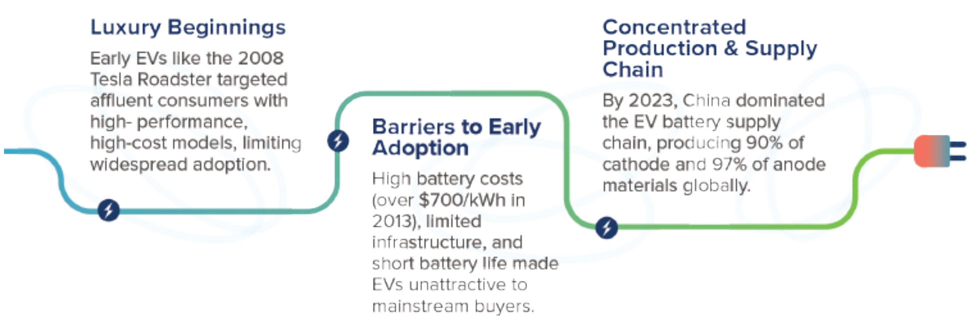


Figure 4: *The Early Evolution of Electric Vehicles:*

2.2. MARKET EXPANSION AND BATTERY PRICE DECLINE

From 2015 onward, the global EV landscape began to shift significantly. Several factors contributed to this transition: technological advancements, economies of scale, policy interventions, and infrastructure investments. Falling to just $138 per kWh by 2024, the sharp decline in battery prices enabled automakers to launch mid-range and budget-friendly EV models (BloombergNEF, 2023). Companies, such as Nissan (Leaf), Hyundai (Ioniq and Kona EVs), and Volkswagen (ID series) launched mass-market electric vehicles targeting middle-class consumers in both developed and emerging markets. By 2024, battery pack prices dropped even further to around $128/kWh, with cell-level costs reaching $99/kWh, driven by falling raw material prices and increased global manufacturing capacity (International Energy Agency, 2024). Additionally, lithium, cobalt, and nickel prices all declined significantly due to oversupply, allowing battery production costs to stabilize and further drop after temporary spikes in 2022 (International Energy Agency, 2024). Figure 2 shows the downward trend in volume-weighted average lithium-ion battery pack and cell prices from 2013 to 2024, illustrating the sustained cost reductions that underpin broader EV adoption.

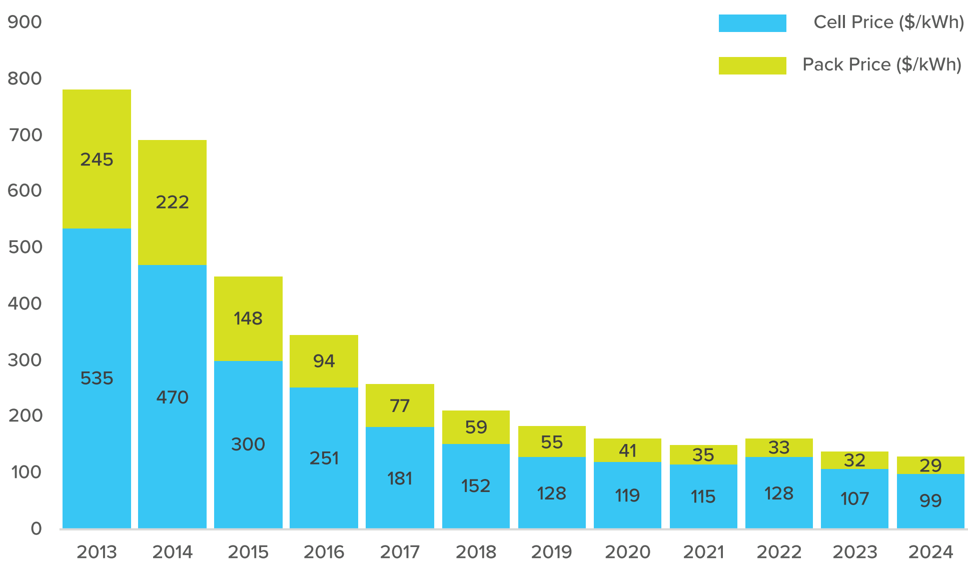


Figure 5: *Battery Price Trend [Source: Bloomberg]*

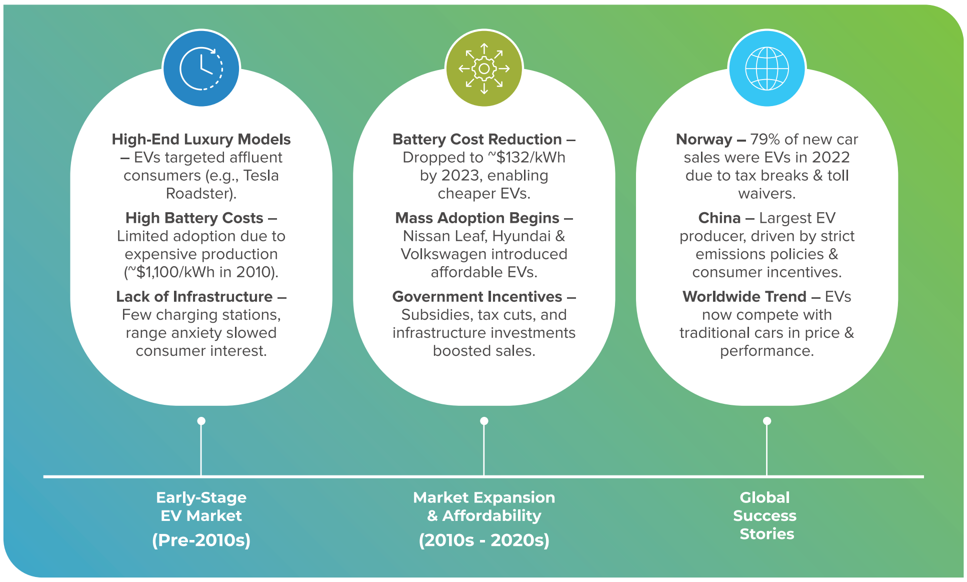
2.3. POLICY SUPPORT AND REGIONAL LEADERSHIP

The expansion was not only driven by cost parity but also by strategic government support and market diversification. Countries with strong EV policies, such as Norway, Netherlands, China, and South Korea provided incentives, including tax exemptions, purchase rebates, free parking, access to bus lanes, and national charging infrastructure rollouts. For instance, sustained policy support in Norway led to EVs accounting for 79% of new car sales in 2022, supported by robust charging stations available every 50 km across major roads (Innovation News Network, 2024).

China, now the global leader in EV production and sales, adopted a multi-pronged approach: large-scale production subsidies, mandated quotas for electric vehicle sales, and support for local battery manufacturing through firms like CATL and BYD. In 2023 alone, China sold over 8 million EVs, with EVs comprising 30% of all new car sales (Reuters, 2025). Similarly, the United States ramped up its EV incentives under the Inflation Reduction Act, offering tax credits up to $7,500 and investments in battery supply chains and public chargers (IEA, 2024). Europe and the United States still import 20–30% of their EV batteries, but investments in domestic production are helping reduce this dependence (International Energy Agency, 2024). International collaboration also supported regional expansion, with Korean, Japanese, and Chinese battery companies investing in giga factories across the EU and the U.S. (International Energy Agency, 2024).

2.4. SEGMENT DIVERSIFICATION AND NEW USERS

Automakers have also diversified their offerings across vehicle categories—beyond passenger cars to include commercial vans, pickup trucks, two- and three-wheelers, and public buses. This broadened the EV user base to include ride-hailing services, last-mile delivery operators, and public transit agencies. For instance, in Europe, Amazon, DHL, and FedEx have begun electrifying their fleets to meet emission targets and reduce operational costs (McKinsey & Company, 2024). Electrification of heavy-duty vehicles is also accelerating, with more than 10,000 electric buses and trucks registered globally in 2023 (International Energy Agency, 2024). Battery chemistries, such as lithium iron phosphate (LFP), now account for more than 40% of global EV battery capacity, especially in light commercial and city transit segments (International Energy Agency, 2024).



2.5. REGIONAL MARKET DYNAMICS AND ADOPTION PATTERNS

The pace of electric vehicle (EV) adoption varies across regions, shaped by infrastructure, economic conditions, and policy support. In Europe, EVs represented nearly 25% of new car registrations in 2023, driven by stringent emissions regulations and substantial investment in charging infrastructure (Mobility Portal 2025). The United States has seen steady growth, led by Tesla's market leadership and consumer demand for performance-oriented vehicles (McIntyre 2025), though adoption faces hurdles like uneven policy frameworks and insufficient charging networks (Zargary 2023). In contrast, China's government-led push for domestic production and strong incentives has made it the global leader in EV sales, accounting for nearly 60% of global sales and producing over 400 GWh of EV batteries in 2023, 12% of which were exported (Fastmarkets 2025; BBVA

Research 2023; International Energy Agency 2024). To respond to supply chain challenges, the US and EU ramped up domestic battery production by 45% and 25%, respectively, during the same period (International Energy Agency 2024).

Astute Analytica 2025 projects that the luxury EV segment alone will reach a market size of $72,798 billion by 2050, growing at a CAGR of 18.02% in the rapidly expanding global EV market. Advancements in battery technology will fuel this growth with improved charging infrastructure and supportive emissions-reduction policies. However, challenges remain, including fluctuating demand, competition from hybrid models, and concerns about charging reliability. Automakers will need to balance innovation and affordability to ensure broader accessibility while maintaining profitability.

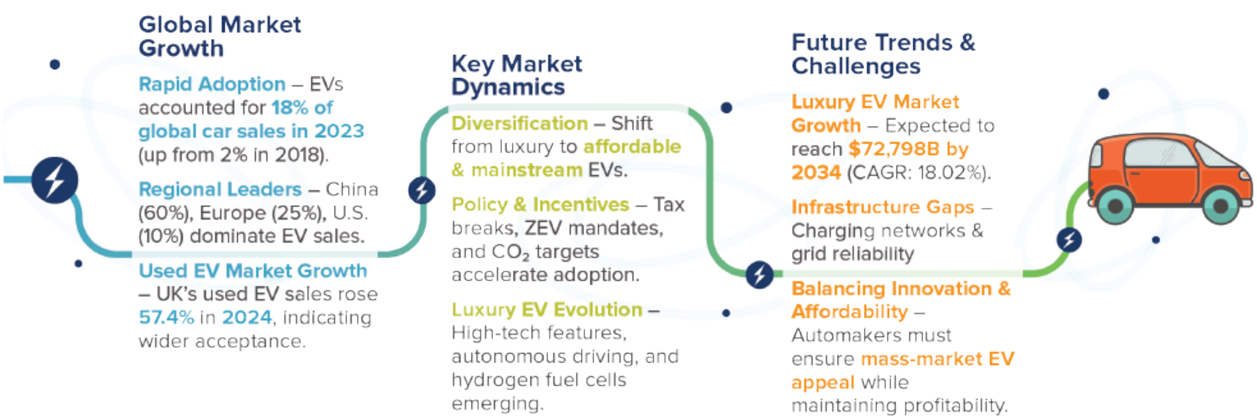


Figure 6: Recent Trends in Global Electric Vehicle Adoption

2.6. MARKET EXPANSION AND DIVERSIFICATION

The electric vehicle (EV) market has developed from a niche dominated by luxury automakers to a diverse and rapidly expanding global industry. Technological advancements and declining production costs have enabled a broader range of manufacturers to enter the market, increasing competition and driving innovation. As a result, EVs have become more accessible to a wider audience. In 2023, electric cars accounted for 18% of all global car sales—up from 14% in 2022 and just 2% in 2018, highlighting the maturing nature of the market (International Energy Agency, 2024). Global EV sales reached nearly 14 million in 2023, marking a 35% year-over-year increase. China led the market with 60% of sales, followed by Europe at 25% and the United States at 10%, driven by supportive policies and growing consumer demand.

Government incentives, emissions targets, and Zero-Emission Vehicle (ZEV) mandates have been key drivers of this growth, alongside investments in charging infrastructure that have alleviated range anxiety. In 2024, the UK's used EV market also showed strong momentum, growing 57.4% to 188,382 units—evidence of increasing mainstream acceptance. However, automakers have cautioned against overly aggressive sales targets; for example, Jaguar Land Rover has urged balanced regulations to sustain long-term investment (International Council on Clean Transportation, 2020). Meanwhile, the luxury EV segment continues to advance with features such as autonomous driving, high-performance batteries, and hydrogen fuel-cell technologies. The fuel-cell luxury EV market alone is expected to grow at a CAGR of 21.8% between 2023 and 2030, signaling strong investor confidence in clean energy alternatives (Market Research Future 2025).

Global Market Growth & Adoption

EV Sales Surge: Electric car sales reached nearly 14 million in 2023, up 35% from 2022, representing 18% of global vehicle sales.

Regional Leaders: China (60%), Europe (25%), and the U.S. (10%) dominate global EV sales, driven by strong policies and incentives.

Diversification & Accessibility

More Choices: EV offerings expanded beyond luxury brands, becoming more affordable and accessible to mainstream consumers.

Used EV Boom: UK's used EV market grew 57.4% in 2024, reflecting increasing trust and demand in the secondary market.

Technology & Policy Drivers

Government Support: ZEV mandates, tax breaks, and emissions targets fuel adoption and infrastructure growth.

Luxury Tech Evolution: High-end EVs feature autonomous systems and fuel-cell tech, with the luxury fuel-cell EV market growing at 21.8% CAGR (2023–2030).

***Figure 7:** Key Global Trends Driving Electric Vehicle Market Expansion*

SECTION II:

CONSUMER PREPAREDNESS

3.1.
CONSUMER ADOPTION AND AFFORDABILITY CHALLENGES

Significant affordability challenges have hindered the transition from Internal Combustion Engine (ICE) vehicles to Electric Vehicles (EVs), primarily stemming from the price disparity between these two vehicle types. As shown in Figure 5, while the average price of ICE vehicles has remained relatively stable over the years, EVs have experienced a gradual decrease in costs. This reduction is primarily because of advancements in battery technology, economies of scale in EV production, and government incentives aimed at promoting electric mobility (International Energy Agency, 2023.

Despite these improvements, EVs remain more expensive than their ICE counterparts, especially in emerging markets where upfront costs heavily influence purchasing decisions. The higher initial cost of EVs can be attributed to the expensive lithium-ion batteries that power them, as well as limited local production capabilities in many regions, which results in dependence on costly imports (MIT Center for Energy and Environmental Policy Research 2023). On the other hand, ICE vehicles continue to dominate the market because of their established manufacturing infrastructure, readily available servicing, and lower upfront costs. This persistent price gap poses a significant challenge to consumer adoption. For many potential buyers, especially those in middle- or low-income brackets, the financial barriers outweigh the long-term savings associated with lower operating and maintenance costs of EVs (CarEdge 2025).

The following graph (Figure 6) highlights the comparative trends in average prices for ICE vehicles and EVs from 2019 to 2024, demonstrating the ongoing challenge of affordability in the EV market.

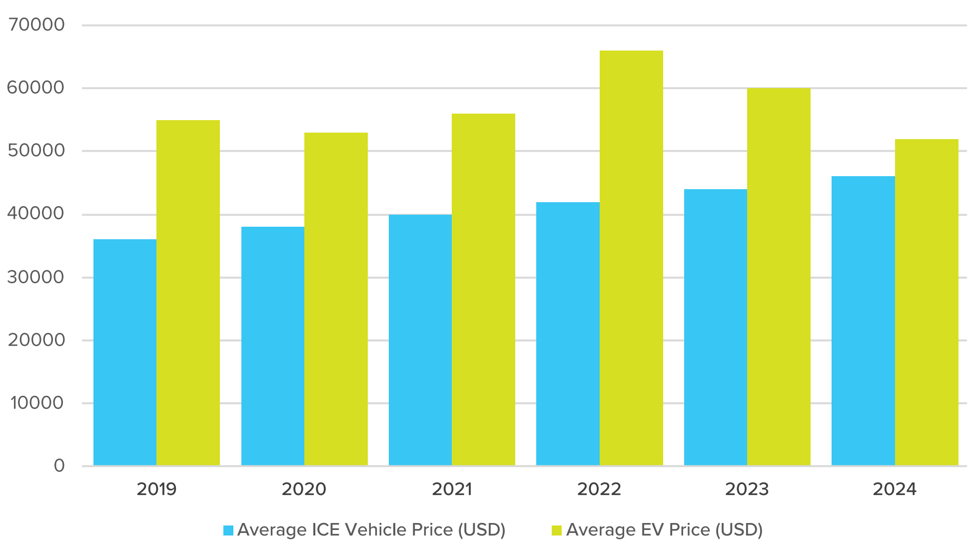


***Figure 8:** Average Vehicle Prices (2019–2024) – ICE vs. EV*

This affordability gap is even more pronounced in the Pakistani market, where EVs remain significantly more expensive than their gasoline counterparts. To illustrate this disparity, Table 1 presents a segment-wise comparison of electric and internal combustion engine vehicles, based on local market data compiled from multiple sources, underscoring the financial barrier faced by average consumers.

Table 1: Segment-wise Price Difference – ICE vs EV

Car Type/Segment	ICE Vehicle Price (PKR/USD)	EV Vehicle Price (PKR/USD)	Percentage Difference
Compact Segment (Entry-Level)	PKR 2.33 - 3.05 mil / $8,300 - $10,900	PKR 3.5 mil / $12,500	20-30% more expensive
Mid-Range Sedan	PKR 9.90 mil / $35,400	PKR 13.99 mil / $50,000	41% more expensive
Compact SUV Segment	PKR 7.899 mil / $28,413	PKR 12.99 mil / $46,726	64% more expensive
Mid-Range SUV Segment	PKR 9.5 mil / $33,929	PKR 15.5 mil / $55,357	63% more expensive
Luxury SUV Segment	PKR 23.0 mil / $82,142	PKR 29.9 mil / $106,785	30% more expensive

3.2. RANGE ANXIETY AND INFRASTRUCTURE AFFORDABILITY

EV adoption in Pakistan faces significant challenges related to affordability, infrastructure, financial accessibility, and regulatory uncertainty. One major barrier is range anxiety, caused by fears that EVs may run out of battery before reaching a charging station. The underdeveloped and unevenly distributed charging infrastructure exacerbates this issue, particularly in semi-urban and rural areas, where EV users have limited and unreliable charging options (CPDI, 2023). Establishing a widespread charging network requires significant investment, but high costs and low demand make it financially unfeasible for private investors without powerful incentives (Khan, Khan & Khan, 2024). Additionally, Pakistan's electricity grid, which still relies on fossil fuels and experiences load-shedding, further complicates the charging process, reducing the reliability of the infrastructure and intensifying consumer concerns (Najmi, 2023; El-Shahat & Hassan, 2024).

Another critical challenge is the lack of workforce readiness for EV expansion. The local industry lacks skilled workers for EV-specific maintenance, and the absence of a robust after-sales service network deters potential buyers (Masood et al., 2024). With most EV parts being imported, vehicle costs remain high, slowing the growth of a sustainable EV ecosystem (PIDE). Moreover, the transition is hindered by regulatory uncertainty, as both the government and private sector continue working to expand the EV ecosystem but face barriers in financing and infrastructure development (Suleman Dawood School of Business, 2025). These factors collectively slow the transition from internal combustion engine (ICE) vehicles to EVs in Pakistan.

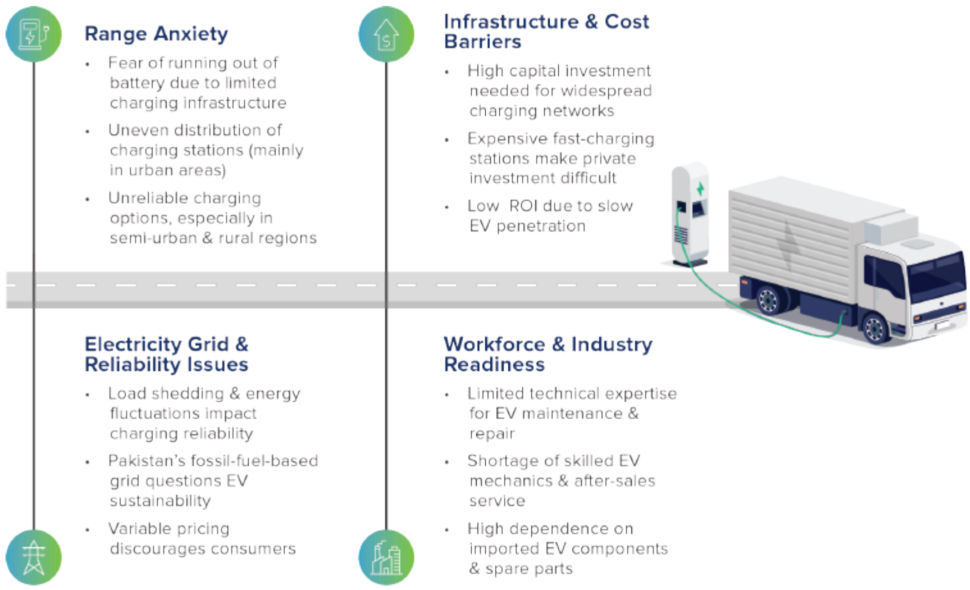


***Figure 9:** Key Barriers to Electric Vehicle (EV) Adoption in Pakistan*

3.3. THE ROLE OF TWO AND THREE-WHEELERS IN ENHANCING EVS AFFORDABILITY IN PAKISTAN

Electric vehicles (EVs) have the potential to become a necessity in Pakistan, and their adoption can be effectively driven through two and three-wheelers, which dominate the country's transport sector. With over 30 million motorcycles and rickshaws on the roads, these vehicles are not just a mode of transport but an essential part of daily life for millions of Pakistanis. In Punjab alone, nearly 90%of all registered vehicles are motorcycles and rickshaws, highlighting their mass-market appeal. Given their affordability compared to four-wheelers, electrification in this segment presents the most practical and scalable entry point for widespread EV adoption (UNDP). Table 2 shows a comparison between conventional fuel-based and electric two-wheelers in Pakistan, based on local market data and price calculations.

Table 2: Price Comparison Between Fuel-Based and Electric Two-Wheelers in Pakistan

Vehicle Model	Type	Price (PKR)	Difference from CD 70 (PKR)	% Change from CD 70 (PKR)
CD 70	Fuel	128,000	—	—
Jolta JE-70D	EV	149,000	+21,000	16.4%
Evee Nisa	EV	159,000	+31,000	24.2%

Based on local market data, electric two-wheelers in Pakistan are becoming increasingly price- competitive with conventional fuel-based motorcycles. While electric models, such as the Jolta JE-70D and Evee Nisa, are priced approximately 16 to 24%shigher than the widely used CD 70, the long-term cost savings from reduced fuel consumption and lower maintenance significantly offset the initial price gap. This narrowing affordability difference positions electric motorcycles as a practical alternative for budget-conscious consumers, especially given the rising cost of gasoline and spare parts.

Electric two and three-wheelers also offer operational and infrastructure advantages over passenger EVs. Their smaller battery packs not only make them cheaper to produce but also reduce reliance on costly public charging infrastructure. Many of these vehicles allow convenient home charging, making them accessible even in areas with underdeveloped commercial charging networks (Urban Unit, 2024).

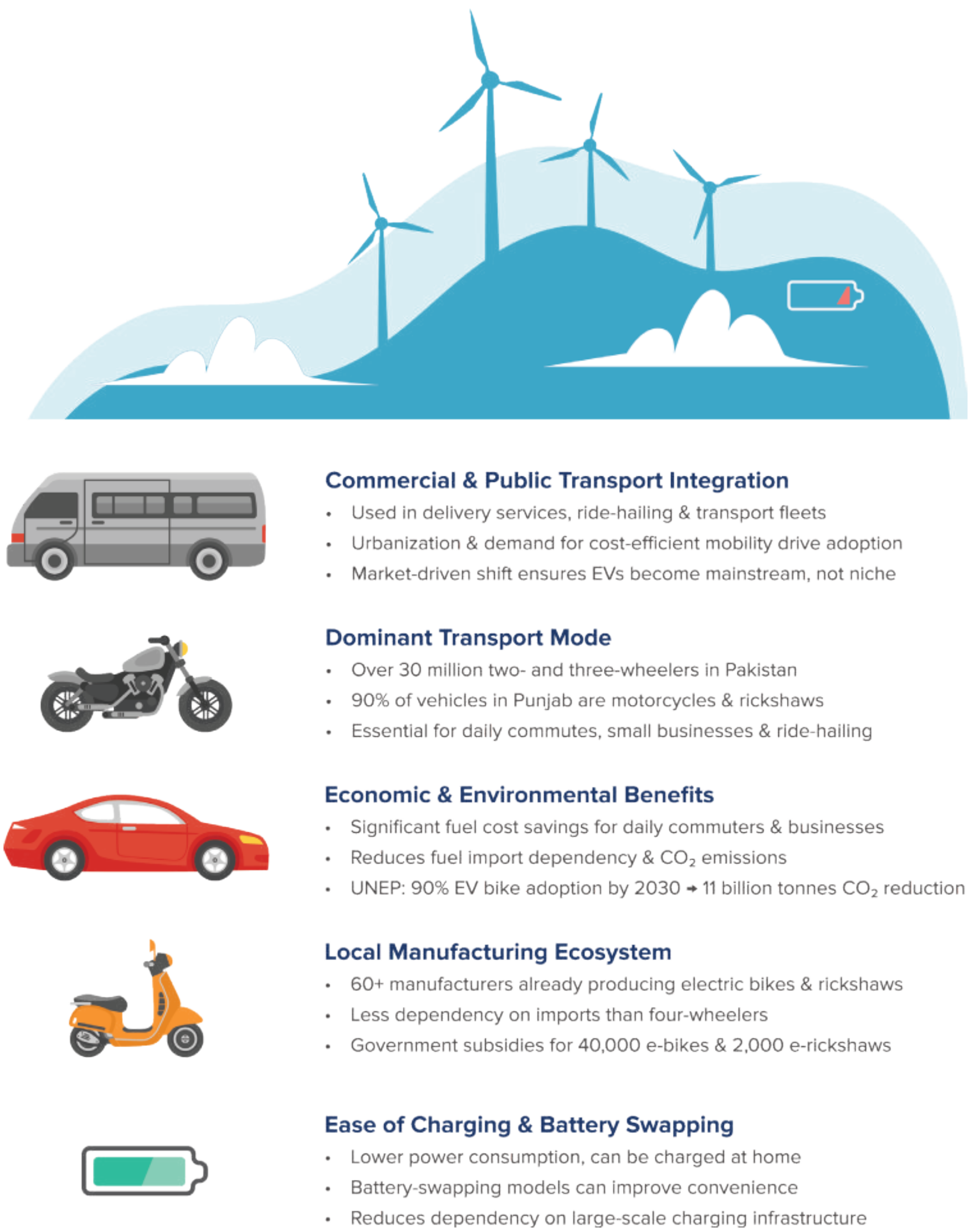


***Figure 10:** Benefits of Electrifying Two- and Three-Wheelers in Pakistan*

3.4.
SCALABLE CHARGING SOLUTIONS FOR ELECTRIC TWO AND THREE-WHEELERS

Building on the increasing affordability and practicality of electric two and three-wheelers in Pakistan, the next step toward accelerating adoption involves enhancing charging accessibility and ensuring continuous vehicle operation. For daily users and commercial operators, such as those in ride-hailing, delivery services, and small-scale businesses, minimizing downtime and maintaining reliability are essential. In this context, battery swapping presents a efficient alternative to conventional charging. It allows users to exchange depleted batteries, ensuring uninterrupted usage and addressing concerns related to range limitations (Khan, Johnson & Khan, 2024).

A key financial challenge in the adoption of electric vehicles is the high upfront cost, largely attributed to the battery, which can represent between 40 to 50% of the total vehicle price. Battery swapping mitigates this challenge by enabling users to lease batteries or pay per exchange. This significantly lowers the initial cost of owning an electric vehicle and increases affordability for consumers who may lack access to structured financing or credit systems (Tran, 2024). The availability of standardized battery formats for motorcycles and rickshaws further enhances the feasibility of battery swapping, allowing various manufacturers to integrate with shared infrastructure.

In addition to making electric mobility more affordable and convenient, battery swapping contributes to improved energy efficiency and grid management. Centralized swapping stations can utilize off-peak hours to recharge batteries, thereby reducing the burden on Pakistan's electricity grid. Moreover, integrating these stations with renewable energy sources such as solar power can further decrease grid dependency while supporting the country's clean energy goals (El-Shahat & Hassan, 2024; Prasad, Uchida & Feng, 2024).

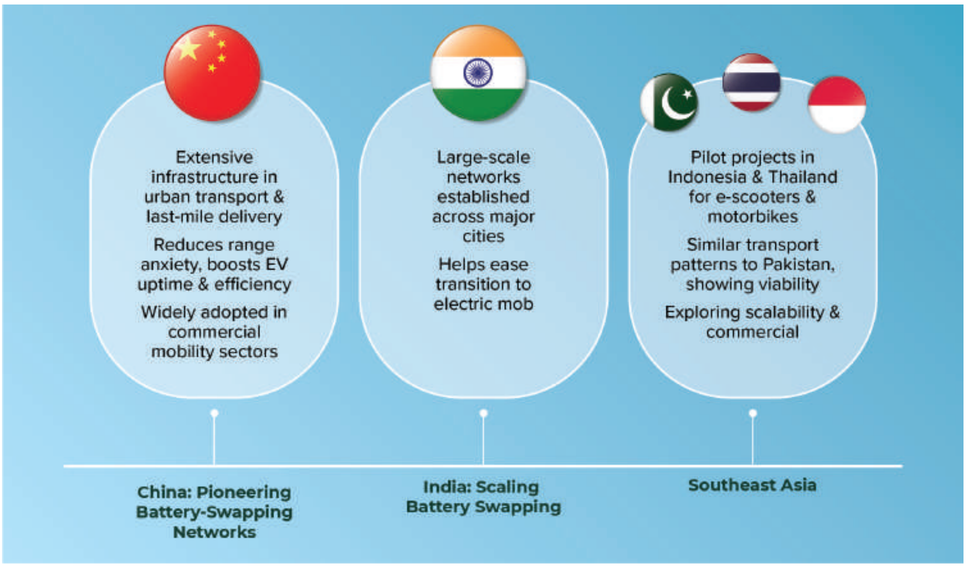


Figure 11: *Role of Battery Swapping in Enabling EV Uptake in Asia*

3.5.
CONVERGENCE PATH IN TERMS OF RETIREMENT OF ICE VEHICLE

Following the growing adoption of electric two and three-wheelers supported by affordability, battery swapping, and localized manufacturing, the next logical step in Pakistan's EV journey is to examine the broader transition from internal combustion engine (ICE) vehicles to electric mobility. This shift is not abrupt but rather a gradual, market-driven evolution shaped by consumer behavior, policy signals, and technological readiness.

Table 3 presents a comparative overview of ICE and electric vehicles across key dimensions such as operational cost, maintenance, environmental impact, and infrastructure development. While ICE vehicles have long been the default choice due to familiarity and availability, EVs now offer a compelling alternative with lower running costs, reduced maintenance, and significant environmental benefits. The expansion of battery swapping and home-charging options further enhances the practicality of EVs, especially in the two and three-wheeler segments that dominate Pakistan's roads.

Table 3: Comparative Overview of ICE Vehicles vs. Electric Vehicles (EVs)

Aspect	ICE Vehicles	Electric Vehicles (EVs)
Fuel/Operation Cost	High, volatile	Low, stable
Maintenance & Spare Parts	Widely available but more frequent	Fewer parts, lower maintenance needs
Environmental Impact	High emissions	Zero tailpipe emissions
Infrastructure	Established fuel stations	Emerging charging/battery-swapping networks
Market Trend	Gradual decline expected	Increasing demand and investment
Consumer Behavior	The default choice historically	Shifting toward EVs for cost savings

As Table 3 illustrates, the growing appeal of EVs is encouraging a phased and sustainable pathway for ICE vehicle retirement. Although fuel stations and ICE support infrastructure remain well established, the market is steadily responding to the economic and environmental value of EVs. Consumer preferences are shifting, particularly in cost-sensitive and high-utilization segments, where the benefits of electrification are most tangible. Ultimately, the pace of this convergence will be set by market forces, supported by strategic policy and private sector innovation, paving the way for a cleaner and more efficient mobility future in Pakistan (IEA, 2021).

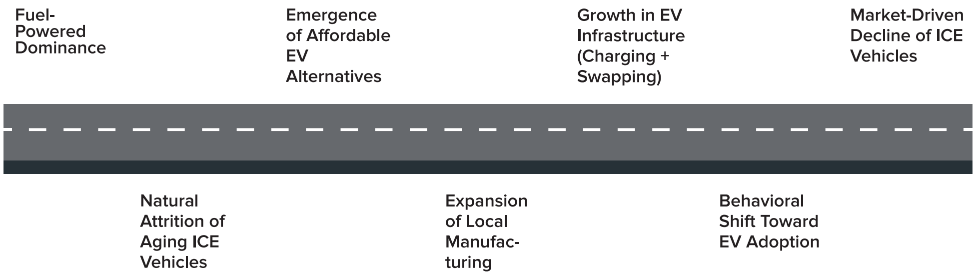


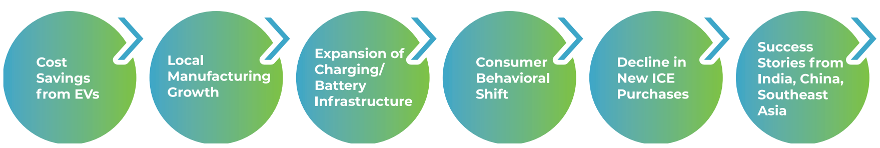
Figure 12: *Phased Roadmap for ICE Vehicle Retirement and EV Integration in Pakistan*

A Virtuous Cycle for EV Adoption in Pakistan

The transition to electric vehicles in Pakistan is gaining momentum, driven initially by the cost-saving potential of EVs. Two- and three-wheelers, which dominate urban mobility, offer significantly lower fuel and maintenance expenses compared to internal combustion engine vehicles. These economic benefits are particularly relevant in Pakistan, where rising fuel prices make cost-efficiency a primary concern for most consumers. As adoption rises, local manufacturing has also expanded. More than 60 domestic manufacturers now produce electric bikes and rickshaws, supported by government incentives and reduced reliance on imported components, fostering a more self-sufficient supply chain.

This local manufacturing growth is complemented by the development of charging infrastructure, especially battery-swapping systems. These systems allow for quick battery replacement, eliminating long wait times and minimizing downtime for commercial users such as delivery services and ride-hailing operators. Battery swapping also reduces reliance on large-scale charging stations, making it more feasible in energy-constrained areas. Successful examples from India and Southeast Asia demonstrate that battery-swapping models can be effectively scaled, offering lessons that are directly applicable to Pakistan's urban landscape and consumer behavior.

As accessibility and infrastructure improve, consumer attitudes shift toward electric mobility. EVs are increasingly viewed as practical and affordable options, which encourages a decline in new ICE vehicle purchases. This behavioral shift reinforces the market momentum toward clean transportation. Regional case studies, particularly from China, India, and Southeast Asia, show how early government action, infrastructure development, and private investment can create a feedback loop that accelerates EV adoption. By learning from these models and reinforcing each stage of the transition, Pakistan can foster a sustainable, long-term shift in its transportation ecosystem.



As Pakistan charts a course toward cleaner mobility, it is important to recognize that the shift from internal combustion engine vehicles to electric mobility will not occur overnight. The retirement of ICE vehicles is expected to unfold progressively, guided by economic signals, infrastructure development, and evolving consumer preferences. Rather than enforcing abrupt changes, a market-led and behaviorally driven approach offers a more sustainable path forward. Lessons from countries like India and China highlight how local solutions such as electric rickshaws and battery-swapping infrastructure can accelerate the transition organically. The following framework illustrates the key elements influencing this gradual shift, emphasizing the interplay between structural, behavioral, and international learning dimensions.

Figure 13: *Key Strategies for Structured transition towards EVs*

Building on the discussion of gradual and market-led transitions in electric vehicle adoption, it becomes important to examine how other countries have addressed similar challenges. Many nations initially struggled with affordability issues and limited consumer confidence, especially in the early stages of adoption. However, through structured interventions such as tax exemptions, purchase subsidies, and investments in infrastructure, they were able to make EVs more accessible and accelerate their uptake. Annex III presents a comparative overview of how different countries implemented phased strategies to reduce cost barriers and support EV adoption, demonstrating the critical role of government action in enabling market transformation. These international experiences offer useful lessons for Pakistan as it designs its path toward sustainable and inclusive electric mobility.

SECTION III:

MANUFACTURER PREPAREDNESS FOR EV

4.1. LOCAL PRODUCTION MODELS: FROM IMPORT DEPENDENCY TO INDUSTRIAL MATURITY

Pakistan's transition to electric mobility hinges not only on demand-side policies but also on the preparedness of local manufacturers and the structure of the production ecosystem. One of the critical choices shaping this landscape is between Completely Built-Up (CBU) and Completely Knocked Down (CKD) production models. CBU refers to fully assembled vehicles imported from abroad. While this method allows quick market entry, it carries high import duties, offers minimal local value addition, and increases reliance on foreign suppliers.

In contrast, the CKD model involves importing EV parts and assembling them domestically. This approach is more cost-effective, encourages local job creation, facilitates technology transfer, and fosters a domestic EV manufacturing base. For Pakistan, especially in the context of the two- and three-wheeler segment—which represents the bulk of urban transport—CKD production is both a practical and scalable solution (Khan, 2024). As these vehicles are used daily for commuting, ride-hailing, and goods delivery, cost reduction through CKD assembly can make EVs financially accessible for working-class consumers. The Indian experience has shown that shifting from fuel-based to electric rickshaws using CKD production significantly reduced costs, even without heavy subsidies (Prasad, Uchida & Feng, 2024).

Figure 14: Comparative Overview of CBU Imports vs. CKD Assembly and Implications for Pakistan's EV Strategy

4.2. EVOLVING INDUSTRY LANDSCAPE AND INVESTMENT MOMENTUM

Pakistan's EV manufacturing ecosystem is still in its early phases, but recent investments signal positive momentum. The ADM Group of China has pledged $350 million toward the EV ecosystem, allocating $250 million for local EV manufacturing plants and $90 million for installing 3,000 charging stations across all provinces (News Desk, 2024). These developments aim to address infrastructure gaps, especially the lack of widespread and reliable public charging facilities. BYD, in collaboration with Mega Motors, is setting up an EV assembly facility near Port Qasim with a target to produce 100,000 electric and hybrid vehicles annually by 2030 (China Pakistan Economic Corridor, 2024). On the domestic front, companies like Sazgar Engineering have already introduced Pakistan's first locally manufactured electric car. Startups such as ezBike, Micropower Labs, and Greenland Motors are focusing on two- and three-wheeler electrification for both personal and commercial use (BR Web Desk, 2024). These efforts collectively represent a foundational shift in the country's vehicle production paradigm—from a reliance on imported finished goods to localized innovation and assembly.

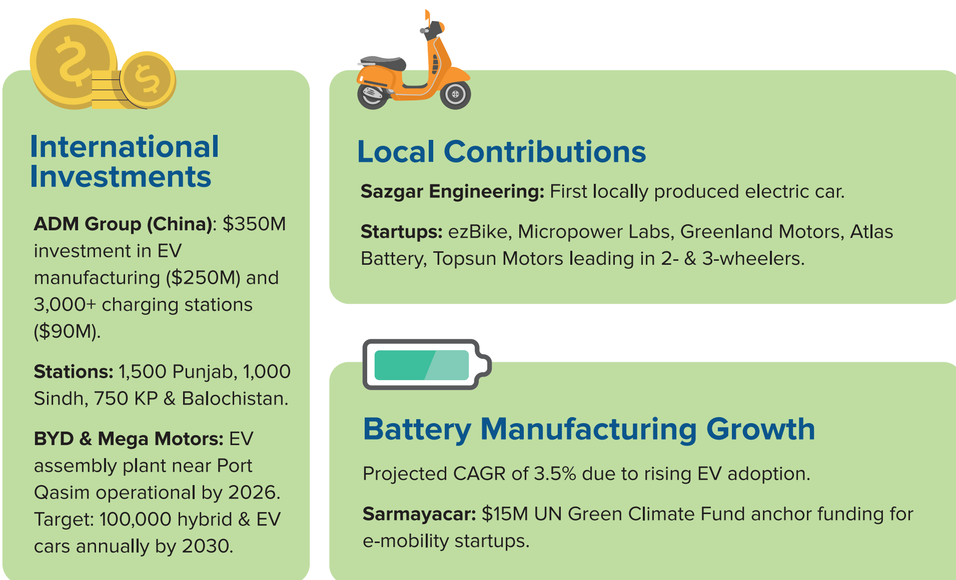


Figure 15: *EV Manufacturing and Startup Momentum in Pakistan*

4.3. LOCALIZED BATTERY MANUFACTURING: A CATALYST FOR AFFORDABILITY AND ENERGY RESILIENCE

Battery costs remain a dominant factor in EV pricing, comprising approximately 40 to 50%of the vehicle's total cost. Developing a localized battery production capability will therefore be critical for making EVs affordable and financially viable on a mass scale (Asghar et al., 2021). Current reliance on imported battery packs exposes the industry to international price volatility, high import tariffs, and logistical disruptions (Cheng et al., 2024). By shifting battery production domestically, Pakistan can not only reduce the cost of EVs but also strengthen supply chain resilience and energy sovereignty (Marchant, 2021).

Why Local Battery Manufacturing Matters for EV Charging Infrastructure

- **Cost Reduction for Charging Stations:** Lowers upfront costs by reducing dependence on imported batteries.
- **Reducing Dependence on Imported Energy Storage:** Ensures a steady supply, reducing vulnerability to global disruptions.
- **Enhanced Financial Viability:** Makes charging infrastructure deployment more financially feasible.

Current Status of Battery Manufacturing in Pakistan

- **Early Developments:** Atlas Battery & Topsun Motors exploring local lead-acid battery production.
- **Sarmayacar Investment:** $15M funding for e-mobility startups focused on battery solutions.
- **Lack of Large-Scale Production:** No current lithium-ion cell production for EVs.

How Other Countries Have Developed Local Battery Manufacturing

- **India:** PLI scheme offers subsidies for local battery production.
- **Vietnam:** Local and international joint ventures for battery manufacturing.
- **Turkey:** Strategic global partnerships to develop domestic supply chains.

Challenges Facing Local Battery Manufacturing in Pakistan

- **High Capital Investment:** Significant financial backing needed for manufacturing plants.
- **Raw Material Availability:** Reliance on imports for critical materials like lithium and cobalt.
- **Lack of Policy Incentives:** No current subsidies or financial incentives for local production.

Figure 16: Strategic Challenges and opportunities in local battery manufacturing

Localized battery production would also benefit EV charging infrastructure. Batteries could be used as backup storage at charging stations, stabilizing costs and reducing grid strain by storing surplus electricity during off-peak hours (Udendhran et al., 2024). Additionally, repurposing used EV batteries for renewable energy storage would lower operational costs and create a more sustainable energy ecosystem for charging stations (Zhu et al., 2024).

Economic Benefits of Local Battery Manufacturing
Reduces reliance on expensive imported lithium-ion batteries.
Lowers EV costs, making them more accessible for consumers and commercial fleets.

Impact on EV Charging Infrastructure
Batteries as backup storage stabilize charging costs and reduce grid strain.
Repurposing used EV batteries for renewable energy storage creates a sustainable ecosystem.

Long-Term Advantages for the Industry
Supports battery repair, recycling, and refurbishment, extending battery life.
Strengthens local supply chains, reducing vulnerability to global disruptions.

Figure 17: Strategic Benefits of Developing Local Battery Manufacturing for EV Ecosystem Growth

4.4. MARKET LANDSCAPE AND STAKEHOLDER PREPAREDNESS ACROSS THE EV VALUE CHAIN

For Pakistan's EV transition to succeed, it is essential to evaluate the readiness of key market players across the entire electric mobility value chain. The following table maps active stakeholders, identifying who is contributing to manufacturing, battery development, charging infrastructure, and mobility services.

Table 4: Key Players in the EV Sector

Segment	Key Players / Activities
EV Assembly & Manufacturing	Sazgar Engineering (electric rickshaws, small EVss, HEVs) BYD & Mega Motors (100,000 EVs/year plant) Sazgar's eVe model)
	Jolta Electric (e-bikes) Evee Electric & ezBike (e-scooters) Vlektra (premium electric bikes)
	Metro EV (e-scooters/models T9 & E8S Pro) Revoo (A11, C32 Pro) Crown Electric Mobility
	YJ Future (Cruise Z9, Zippy E1, Azadi, e-rickshaw) Ramza (A700, TSX, Q70 tri-wheeler) Yes Electromotive (Muva electric rickshaw)
Battery Technology & Manufacturing	Micropower Labs (battery R&D), NUST, PCSIR (industry prototypes & testing) Sarmayacar (GCF-funded battery startup)
Charging Infrastructure	ADM Group (3,000 charging stations rollout), Dewan Motors (BMW chargers), InstaCharge, Shell, Attock Petroleum
Mobility Platforms & Services	ezBike (scooter sharing), Swyft (micro-mobility pilot), Bykea (EV fleet trials), Cargoo (last-mile EV logistics)
Policy & Institutional Support	Engineering Development Board (EDB), Ministry of Industries & Production (NEVP 2025), NEECA (EV tariff regulation), PSQCA (standards and quality certification)

SECTION IV:

FINANCIAL ENABLERS FOR EV TRANSITION IN PAKISTAN

5.1. REFRAMING EV AFFORDABILITY: THE FINANCING GAP IN PAKISTAN

The transition to electric mobility in Pakistan, particularly for two and three-wheelers, is heavily constrained by limited financing options. Despite their lower operational costs and environmental benefits, electric vehicles remain unaffordable for most consumers because of high upfront prices, primarily driven by battery costs, which can account for nearly half the vehicle's price. Structured financing options for low-income and informal sector users, who rely heavily on these vehicles, are largely unavailable. Conventional bank loans are difficult to access because of high interest rates, collateral requirements, and the lack of formal credit histories. As a result, even existing electric vehicle loan schemes from banks like HBL and JS Bank have seen very low uptake (Kiani, 2024).

Globally, countries such as India, Kenya, and Vietnam have successfully implemented inclusive financing models that could be adapted in Pakistan. These include lease-to-own and pay-as-you drive arrangements that bundle financing with insurance, maintenance, and digital tracking. In India, companies like OTO Capital and Mufin Finance offer flexible credit for informal workers, while Kenya's BasiGo provides electric buses through usage-based payments. This fintech led models help ensure repayment through telematics and performance-linked contracts. By adopting similar approaches, Pakistan can enable gig workers, delivery riders, and small fleet operators to access electric vehicles, creating a pathway for large-scale adoption through tailored, accessible financing mechanisms.

5.2. INNOVATIVE FINANCIAL INSTRUMENTS: UNLOCKING GREEN AND CLIMATE-ALIGNED CAPITAL

Beyond conventional banking channels, the transition to electric mobility in Pakistan requires creative and sustainable financing mechanisms tailored to local market dynamics. To accelerate EV adoption—particularly among low- and middle-income consumers—Pakistan must tap into global climate finance and develop alternative instruments that lower upfront costs and improve credit access.

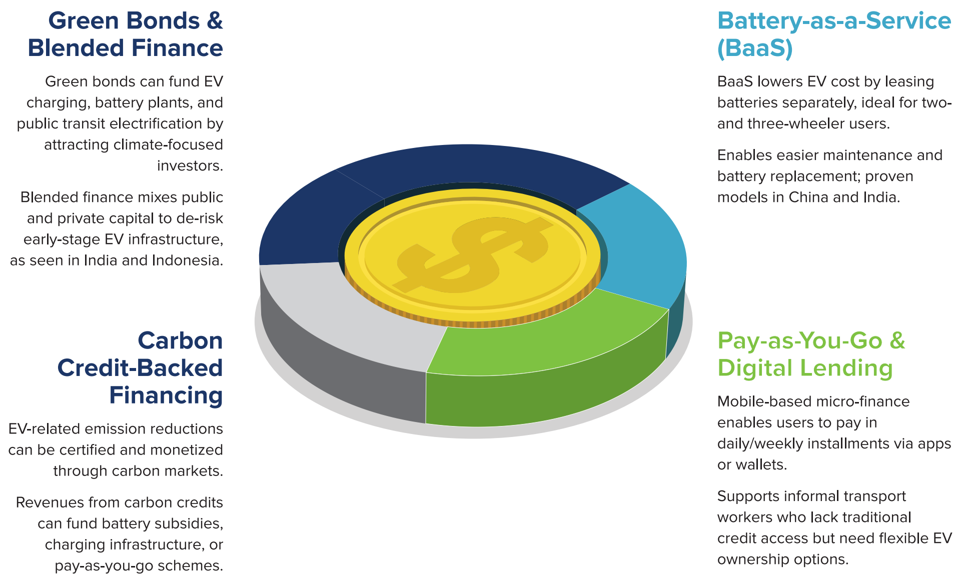


Figure 18: *Innovative Financing Models for EV Infrastructure*

5.3. INFRASTRUCTURE INVESTMENT AND ROI: BREAKING THE FUNDING DEADLOCK

The expansion of electric vehicle (EV) charging infrastructure in Pakistan is trapped in a classic “chicken-and-egg” dilemma. On one hand, private investors are hesitant to finance charging stations until a critical mass of EV users justifies the investment. On the other hand, consumers are reluctant to purchase EVs without the assurance of a reliable and accessible charging network. This circular dependency has stalled infrastructure development, especially outside of major cities.

In Pakistan, this challenge is further aggravated by a mix of systemic issues: difficulties in acquiring urban land for station construction, the instability of the national electricity grid, and the absence of clear, enforceable EV targets or long-term policy guarantees. Without transparent regulatory signals and investment protection, the private sector remains wary of engaging in high-capital, low-certainty projects. To address this deadlock, Pakistan must develop a comprehensive and commercially viable model for Charge Point Operators (CPOs). These operators, often private or semi-private entities, are central to building and operating charging networks. For Pakistan to attract investment in this domain, three foundational pillars are essential:

5.3.1 | Incentivizing CPO Participation in Policy and Financial Support

The government can de-risk the EV infrastructure space by offering structured incentives to early-stage investors. These may include:

- Guaranteed minimum revenue or viability gap funding in the initial years of operation.
- Preferential electricity tariffs for public charging stations to ensure profit margins.
- Streamlined licensing and land acquisition processes, particularly for high-traffic urban corridors.

Global precedents show this model’s efficacy. In China, the government introduced generous subsidies, tax incentives, and revenue guarantees to encourage CPO investments. South Korea developed government-owned charging hubs that were later leased to private operators once the demand matured (Richter, 2023). Similar transitional models could be tailored for Pakistan’s urban centers.

5.3.2 | Space Leasing Models and Commercial Synergies

One highly replicable approach is space leasing, wherein commercial venues—such as shopping malls, office complexes, gas stations, and bus terminals—allocate parking or forecourt space to CPOs for installing EV chargers. In this arrangement:

- CPOs finance and operate the charging station.
- Property owners benefit from lease payments and increased customer dwell time.
- EV users gain access to convenient and safe locations for charging.

This dual-benefit model is widely adopted in Europe and North America, where locations like IKEA, Walmart, and motorway service areas host high-speed charging hubs. In Pakistan, this could be piloted at motorway rest areas, transport terminals, or fuel stations operated by PSO and other petroleum marketing companies.

5.3.3 | International Climate Finance and Donor-Backed Investments

Given the climate-aligned nature of EV infrastructure, Pakistan can tap into concessional financing and grants from multilateral development institutions. Agencies like the Asian Development Bank (ADB), World Bank, Global Environment Facility (GEF), and the UN Green Climate Fund are actively funding EV-related infrastructure in low- and middle-income countries (William Davidson Institute, 2025).

Funding streams can be allocated for:

- Solar-powered EV charging hubs reduce dependency on Pakistan's overburdened grid while improving charging reliability.
- Battery-swapping depots, particularly for commercial fleets and two- or three-wheelers, which reduce the need for fast-charging infrastructure.
- Distribution grid upgrades, including transformers and substation expansion, to support the additional electricity load from high-capacity chargers.

Public-Private Partnership (PPP) frameworks are especially effective in this space. Under such models, the government assumes capital expenditure (CAPEX) responsibility, while private operators manage operations and maintenance (O&M). This model mitigates financial risk and accelerates infrastructure deployment. Successful case studies include South Korea's EV infrastructure roadmap, where 80% of public chargers were installed through PPPs, and the Netherlands, where municipalities co-invest with charging networks while providing real-time user data to optimize deployment (Elywhere, 2024).

5.4.
LESSONS FROM GLOBAL FINANCING MODELS

As Pakistan develops its electric mobility ecosystem, global experiences provide valuable lessons on financing strategies that support both demand and infrastructure. These models highlight various financing instruments such as subsidies, tax incentives, and public-private partnerships (PPP) that have proven effective in accelerating EV adoption. Table 5 provides a comparative overview of global EV financing models, showcasing key financing instruments, implementation strategies, and the resulting affects from countries like India, Kenya, South Korea, the European Union, and China. This highlights their successes in vehicle financing, infrastructure development, and adoption of innovative models.

Table 5: Comparative Overview of Global EV Financing Models

Country/ Region	Key Financing Instruments	Implementation Strategy	Impact / Lessons
India	Interest subvention, demand-side subsidies under the FAME scheme	Public banks offer subsidized loans; central government provides upfront buyer incentives	Boosted two- and three-wheeler adoption; structured credit access helped low-income consumers
Kenya	Climate-linked funds, pay-per-use battery services	Companies like Ampersand and Roam leverage carbon finance and battery leasing models	Enabled affordable electric motorcycles for gig workers; scalable to informal sectors
South Korea	Tax incentives for landlords and businesses installing EV chargers	Incentivized charging infrastructure in residential and commercial complexes	Achieved infrastructure equity; encouraged private sector participation
European Union	Public-private partnerships (PPP), performance-based subsidies	Standardized regulation; co-investment with utilities and private firms	Accelerated charging network build-out; ensured investor confidence
China	State-subsidized infrastructure (battery swapping hubs, fast-charging highways)	Government invested ahead of consumer demand to build confidence and enable rapid adoption	Led to the world's largest EV and charging network; proactive policy drove private sector entry

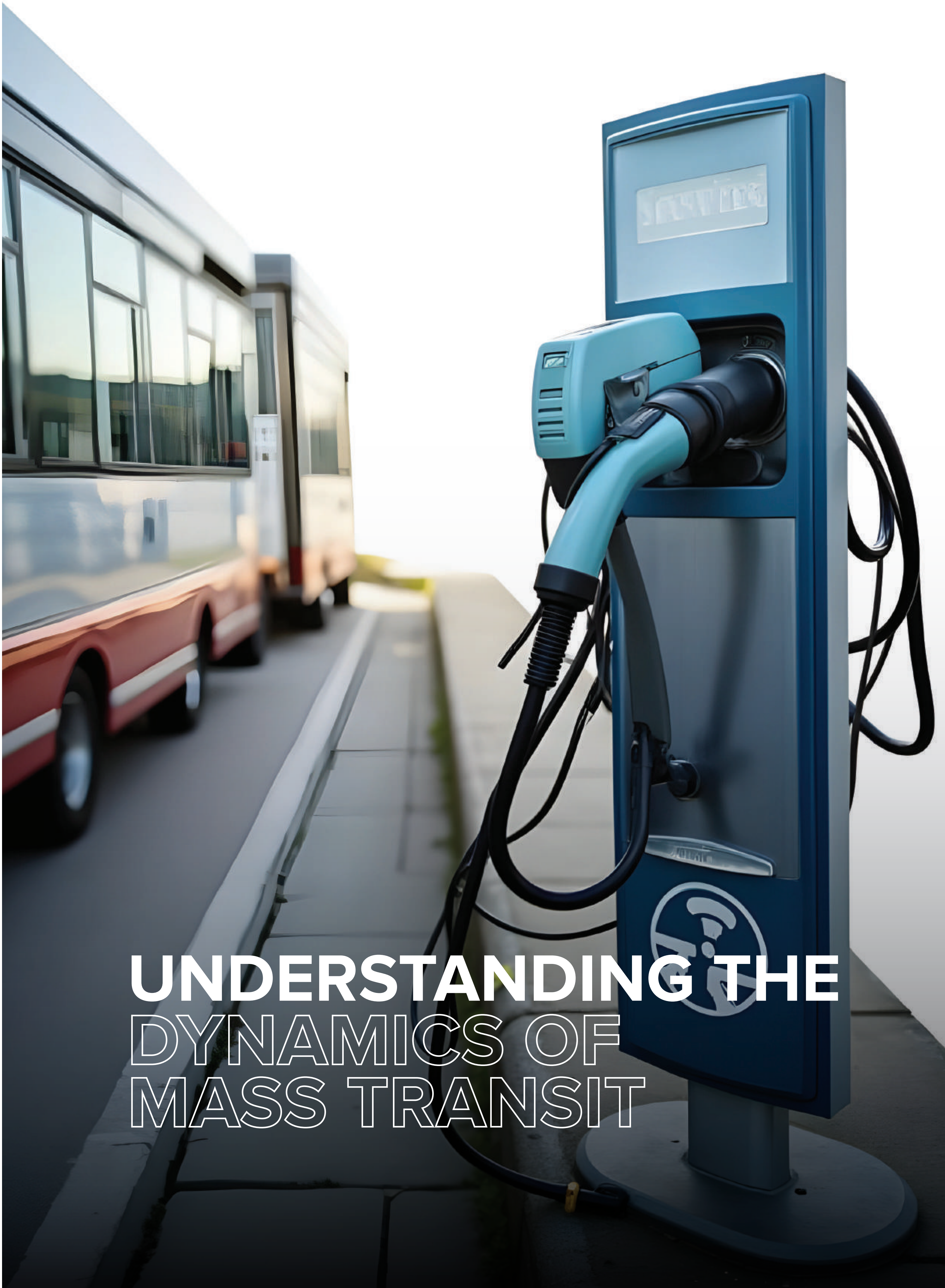
5.5. BUILDING A BANKABLE EV ECOSYSTEM

Financing is not just an enabler—it is the foundation of Pakistan's electric vehicle transition. From consumer affordability to infrastructure expansion, a robust and inclusive financial architecture will determine the success of the national EV strategy.

This architecture must include a mix of mechanisms:

- Targeted purchase subsidies for low-income buyers
- Concessional loans and interest subvention schemes
- Public-private partnerships for charging infrastructure
- Carbon monetization through verified emission reductions
- FinTech-led credit delivery using mobile payments and behavioral risk scoring

By aligning fiscal incentives with institutional financing and climate-aligned capital, Pakistan can move beyond fragmented pilots to a scalable, investment-ready EV market. The ultimate objective is twofold: to make electric mobility affordable and aspirational for users, and to create bankable pathways for manufacturers, operators, and infrastructure developers to thrive.



UNDERSTANDING THE DYNAMICS OF MASS TRANSIT

The transition to electric mobility in Pakistan cannot be complete without addressing the transformation of mass transit systems. Public transport, particularly buses and railways, forms the backbone of urban mobility and plays a critical role in reducing congestion, pollution, and energy dependency. While much focus has been placed on private and small commercial vehicles, the electrification of mass transit presents a far more impactful opportunity in terms of emissions reduction and operational savings. However, this shift requires strategic planning, robust infrastructure, and policy support to overcome high upfront costs and systemic limitations.

6.1. THE ECONOMICS OF TRANSITION: UNDERSTANDING THE COST DYNAMICS OF E-BUSES

The introduction of electric buses in Pakistan brings with it both promise and complexity. While the benefits of e-buses in terms of long-term cost savings and environmental performance are evident, the high upfront investment remains a major barrier. In January 2024, Pakistan imported 160 Higer electric buses at an average price of $143,750 per unit, a figure significantly higher than the cost of traditional diesel buses. This price gap creates a financial challenge, particularly for a developing country where public transport is often subsidized and reliant on constrained municipal budgets.

Despite these challenges, operational savings from e-buses are substantial. In global markets, e-buses have demonstrated the potential to reduce fuel costs by up to 70%. In Chile, operational costs for electric buses average around $0.10 per kilometer, compared to $0.43 for diesel buses (UNEP, 2019). Maintenance requirements are also lower because of the absence of complex internal combustion engines and related components. While the total cost of ownership still includes factors such as battery replacement and the need for charging infrastructure, the financial break-even typically occurs within seven to ten years of service. For Pakistan to capitalize on these long-term gains, financing models like government subsidies, leasing schemes, and public-private partnerships will be critical.

6.2. INFRASTRUCTURE DEVELOPMENT: A PRESSING CHALLENGE

A major hurdle to the widespread adoption of electric buses in Pakistan is the lack of supporting infrastructure. Unlike diesel buses, which can refuel quickly at any gasoline station, e-buses depend on dedicated charging stations. Currently, cities like Lahore, Islamabad, and Karachi have only a handful of operational charging points, limiting the viability of large-scale e-bus deployment. Operational disruptions have already occurred because of inadequate facilities, underscoring the urgent need for a reliable and widespread charging network.

Charging requirements vary based on technology. Fast chargers can recharge a bus in 30 to 90 minutes, while slower systems may take up to six hours. This necessitates the development of strategically located charging depots at bus terminals and key transport nodes. Additionally, Pakistan's power grid, which is already under stress because of load shedding and distribution losses, would face further pressure from the high energy demands of charging stations. Each charging event can draw between 50 and 300 kilowatts, posing a risk of instability if not managed correctly (Singh et al., 2024).

In other countries, such as China, massive investments were made to align power infrastructure with transit electrification. The city of Shenzhen, for instance, spent over USD 1.5 billion to upgrade its power grid, install dedicated substations, and establish battery storage facilities alongside e-bus networks (World Bank, 2021). For Pakistan to replicate such a model, a coordinated approach between urban transport authorities and energy utilities is essential. Alongside infrastructure, technical expertise is also a concern. The maintenance and safe operation of electric buses requires a workforce trained in high-voltage systems, battery management, and electric drivetrains—areas where Pakistan currently lacks institutional capacity. This could lead to operational delays if repairs are needed, as seen in Chile's early e-bus deployment (World Bank, 2021).

6.3. POLICY FRAMEWORK AND GLOBAL PARTNERSHIPS

Government policy and international collaboration play a pivotal role in steering electric public transport. While the National Electric Vehicle Policy (NEVP) outlines incentives for EV adoption, it lacks specific targets and timelines for public transit electrification. This policy ambiguity has led to uncertainty among investors and hindered the development of comprehensive mass transit programs. In contrast, countries like India have set ambitious goals, aiming to electrify 30% of their bus fleets by 2030. Without comparable benchmarks, Pakistan risks falling behind in the regional shift toward cleaner transport.

Moreover, coordination between federal and provincial governments remains fragmented, slowing implementation efforts. Lessons can be drawn from successful international models. Countries such as Chile and Colombia have combined national policies with international financing to drive e-bus adoption. Institutions like the Asian Development Bank and World Bank are actively promoting electric public transport in developing countries, offering financial and technical support. Similarly, initiatives under China's Belt and Road Initiative and the China-Pakistan Economic Corridor offer an opportunity for Pakistan to benefit from infrastructure investment and EV manufacturing partnerships (European Commission, 2021). International financing plays a crucial role, with institutions like the ADB and World Bank pushing for climate-friendly solutions. However, bureaucratic delays have hindered progress (Majid, Kumar & Ahmed, 2024).

Reviving the Electric Railway: A Systemic Opportunity

Pakistan's limited yet pioneering experience with railway electrification in the late 20th century provides a valuable precedent for sustainable, large-scale transport modernization. In 1979, Pakistan Railways successfully commissioned a 295-kilometer electrified corridor between Lahore and Khanewal, using a 25kV AC overhead catenary system, with technical assistance from ASEA of Sweden. This early effort demonstrated both the technical feasibility and institutional capacity to operate electric rail in Pakistan. However, the project was later decommissioned because of chronic underinvestment, shortages of critical spare parts, and unreliable electricity supply—challenges that reflect the broader systemic issues of that period.

Today, reviving and scaling up railway electrification presents a unique opportunity—not only for transport sector decarbonization, but also for addressing deep-rooted inefficiencies in Pakistan's energy system. Diesel locomotives currently cost an estimated PKR 700–800 per kilometer to operate, factoring in fuel, maintenance, and lifecycle wear. In contrast, electric locomotives—powered by grid electricity or renewables—can reduce per-kilometer operating costs by 35–50%, primarily due to lower energy prices and reduced mechanical complexity (IRJ, 2023). The switch from diesel to electric traction also cuts down greenhouse gas emissions and reduces local air pollution, particularly along major freight corridors.

Crucially, electrified railways offer a systemic solution to Pakistan's ballooning power sector circular debt, which reached PKR 2.703 trillion in 2023. A large portion of this debt stems from capacity payments made to independent power producers (IPPs) for electricity that remains unused, especially during off-peak hours. These fixed payments, made regardless of actual consumption, place immense strain on public finances and drive up electricity tariffs for consumers and industry alike.

Electric railways, particularly freight trains operating during night hours, can act as stable, high-volume anchor loads, absorbing this surplus electricity that would otherwise go to waste. By synchronizing rail operations with grid availability, Pakistan can turn underutilized generation capacity into productive economic output, improving both the load factor of power plants and the revenue flows for distribution companies. Working together, the transport and energy industries could greatly lower costs while making the delivery system cleaner and more efficient.

The fuel savings alone underscore the value of this transition. For example, a single diesel locomotive operating on the Peshawar–Karachi route (1,872 km) consumes approximately 7,488 liters of diesel per one-way trip—equivalent to over PKR 2 million per journey at current prices. Shifting this route to electric traction would reduce that cost to around PKR 892,000, saving over PKR 1.13 million per trip. Annually, with just 100 trips on this corridor, the savings would exceed PKR 113 million per locomotive, and even more if scaled across multiple trains and corridors.

In summary, railway electrification is not merely a transport upgrade—it is an integrated economic strategy. It addresses multiple national priorities: reducing dependence on imported fuel, improving power sector utilization, cutting operational costs, and enabling low-carbon development. By leveraging existing energy infrastructure and aligning transport needs with grid realities, Pakistan can unlock system-wide efficiencies, alleviate circular debt, and build a more resilient, climate-smart future.

SPECIAL CHAPTER:

SMART CHARGING INFRASTRUCTURE

UNLOCKING THE ROLE OF DISTRIBUTED GENERATION

7.1. THE CASE FOR DISTRIBUTED GENERATION IN PAKISTAN'S EV TRANSITION

As Pakistan accelerates its transition to electric vehicles (EVs), the resilience of its energy ecosystem becomes a cornerstone of success. Unlike traditional vehicles that depend on centralized fuel stations, EVs require consistent and reliable electricity access. This need poses a significant challenge in Pakistan, where the national grid is already under stress from frequent power outages, high transmission losses, and mismatches between energy supply and demand (Science Direct, 2025). In this context, Distributed Generation (DG)—the localized production of electricity through renewable sources such as solar and wind—offers a vital alternative to conventional, centralized power systems.

DG solutions reduce reliance on long-distance transmission infrastructure by enabling power to be generated closer to the point of consumption. This is especially valuable for EV charging stations in grid-weak, peri-urban, or rural areas. Global leaders like China and Germany have effectively integrated DG with EV infrastructure, using renewable energy and battery storage to stabilize charging networks and reduce grid strain (Kumar et al., 2024). Pakistan has strong potential to follow suit, with high solar irradiance levels averaging 5.3 $kWh/m^2/day$ and viable wind corridors in Sindh and Balochistan. When paired with battery storage, DG systems can power semi-autonomous EV charging stations, improve energy reliability, and reduce dependence on fossil fuels—ultimately supporting a more sustainable and secure EV ecosystem (Singh et al., 2024).

Renewable Integration:
Solar, Wind, and Hybrid Models

Solar energy presents the most promising renewable option for Pakistan's EV charging infrastructure. Rooftop and canopy solar panels at charging hubs can supply daytime demand while lowering long-term operational costs. Successful models from India and the U.S., such as Tesla's solar-integrated Superchargers, illustrate how decentralized solar systems reduce reliance on the central grid (Affonso & Kezunovic, 2019).

Hybrid systems combining solar and wind further enhance stability, especially in regions like Karachi and Thatta, which have favorable wind speeds. These combinations ensure continuous power generation and allow EV hubs to operate off-grid if needed. Moreover, Power-to-Vehicle (P2V) approaches allow EVs to absorb excess renewable energy during off-peak times—typically at night—stabilizing the grid and improving renewable energy economics (Lund et al., 2020).

Pakistan can replicate such models to enable highway and rural EV charging, reduce curtailment losses in renewable generation, and maximize energy utilization without burdening the grid.

7.2. BATTERY ENERGY STORAGE SYSTEMS (BESS): POWERING RESILIENT CHARGING NETWORKS

As electric vehicle (EV) adoption increases, ensuring a reliable and resilient energy supply becomes essential, particularly in countries like Pakistan where grid instability, load shedding, and voltage fluctuations are common. Battery Energy Storage Systems (BESS) offer a practical solution by storing electricity during periods of low demand or high renewable generation and releasing it when energy is needed. This supports continuous power for EV charging stations, especially those with fast-charging capabilities that require high energy input in short durations (Kamran, 2023).

BESS also facilitates peak shaving, allowing energy to be stored when electricity rates are low and used when prices or demand rise, improving cost efficiency and financial sustainability for charging operators (Sarda et al., 2024). In Pakistan's time-of-use tariff system, this approach can significantly reduce operational costs and increase profit margins. Globally, BESS has demonstrated its effectiveness. In California, Tesla's Power-pack and Mega-pack systems have improved energy reliability, while in the Netherlands, battery-buffered charging stations operated by Fastned provide consistent fast charging even when the grid is constrained (Zheng et al., 2024).

For Pakistan, particularly in megacities like Lahore, Karachi, and Peshawar, BESS can be transformative. These cities experience significant power fluctuations and are home to the bulk of EV pilot programs and urban mobility schemes. Fast-charging hubs in these urban areas could integrate BESS to guarantee uninterrupted operations during peak hours or blackouts, ensuring consistent charging access for both individual EV users and electric fleet operators. Moreover, BESS-equipped hubs could be strategically installed along highways and logistics corridors, offering backup power where grid connectivity is unreliable or intermittent.

In the long term, integrating BESS with renewable energy systems such as rooftop solar or hybrid wind installations can enable off-grid or microgrid charging stations, particularly in peri-urban or rural regions. These systems reduce grid dependency while maximizing the use of clean energy. Additionally, the modular nature of BESS systems allows for scalability, meaning that EV charging stations can incrementally increase storage capacity as demand grows rather than over investing upfront.

To encourage BESS adoption, policy support and financial mechanisms are crucial. Internationally, government incentives such as tax rebates, concessional loans, and feed-in tariff guarantees have supported large-scale energy storage deployment. Pakistan could follow similar models by introducing:

- Capital subsidies for BESS-equipped stations
- Time of use tariff incentives
- Net metering policies for renewable-charged BESS systems
- Grants or concessional financing through international agencies like the ADB or Green Climate Fund

In conclusion, Battery Energy Storage Systems (BESS) are not merely supportive technologies but foundational enablers of resilient, scalable, and low-carbon EV charging infrastructure. As Pakistan scales up its electric mobility transition, integrating BESS with distributed renewable generation will be essential to ensuring grid stability, reducing operational costs, and expanding access to charging in underserved areas. Countries across Asia, Europe, and North America have already demonstrated successful models of smart EV ecosystems that combine solar, wind, battery storage, and grid-integrated solutions. These global practices not only show the technical feasibility of such systems but also their commercial and policy-driven viability. Table A1 in the annex, titled “Global Examples of Smart EV Ecosystem,” presents an overview of leading international initiatives, their energy sources, impacts, and financing strategies, offering valuable insights for localized adoption in Pakistan.

7.3. FINANCIAL VIABILITY OF SMART CHARGING MODELS

As Pakistan scales its EV infrastructure, understanding the comparative economics of different charging models becomes essential for investors, policymakers, and urban planners. Smart charging models can be broadly categorized into three configurations: grid-only, solar-only, and solar combined with battery storage. Each has distinct cost structures, operational dynamics, and implications for profitability.

The following table presents a scenario-based analysis of these models, assuming a daily charging demand of 400 to 600 kWh and a fixed consumer charging rate of PKR 110 per kWh. This linear comparison assumes no subsidies, downtime, or financing costs and uses current NEPRA rates as a benchmark for grid-supplied electricity.

Table 6: Comparative Financial Scenarios for EV Charging Infrastructure (in Millions PKR)

Component	Scenario 1 Grid Only	Scenario 2 Solar Only	Scenario 3 Solar + Battery
EV Charger Cost (240 KW)	18.2 million PKR	18.2 million PKR	18.2 million PKR
Civil Works	8.0 million PKR	–	–
Solar Installation – 280kWh	–	28.2 million PKR	28.2 million PKR
Battery Bank-280 kWh	–	–	14.65 million PKR
Total Initial Cost	26.2 million PKR	46.4 million PKR	61.05 million PKR
Applicable Demand (kWh)	400–600	60% of 400–600	100% of 400–600
		(240 – 360)	
Charging Rate (PKR/ kWh)	110	110	110
NEPRA Cost (PKR/kWh)	39.70	–	–
Daily Revenue	44000 – 66000	26400 – 39,600	44000 - 66000

Profit Margin	63.91 %	100 %	100 %
Daily Profit (PKR)	28,120 – 42,180	26,400 – 39,600	44,000 – 66,000
Yearly Profit (PKR)	10.26M – 15.4M	9.63M – 14.45M	16.06M – 24.09M
10-Year Profit (PKR)	102.6M – 154.0M	96.3M – 144.5M	160.6M – 240.9M
Net Gain in 10 Years (PKR)	76.4M – 127.8M	49.9M – 98.1M	99.55M – 179.85M
20-Year Profit (PKR)	205.2M – 308.0M	192.6M – 289.0M	321.2M – 481.8M
Net Gain in 20 Years (PKR)	179.0M – 281.8M	146.2M – 242.6M	260.15M – 420.75M
25-Year Profit (PKR)	256.5M – 385.0M	240.75M – 361.25M	401.5M – 602.25M
Net Gain in 25 Years (PKR)	230.3M – 358.8M	194.35M – 314.85M	340.45M – 541.2M
Depreciation cost (Per Year)	-	1.0716 million	1.6283 million
Payback Period (Years)	1.70 – 2.55	3.21 – 4.82	2.53 – 3.80
NPV (10 yrs, 10% Rate)	36.84M – 68.43M	12.77M – 42.39M	37.63M – 86.97M

Scenario 1: Grid-Only Model – Low Capex, Fast Returns, Low Operational Margin

This configuration requires the lowest initial investment at 26.2 million PKR, covering the EV charger and civil works. With an expected demand of 400–600 kWh/day, it leverages the existing national grid for power supply and delivers daily profits between 28,120 and 42,180 PKR, depending on utilization rates.

Advantages

- The quickest payback period: 1.70 to 2.55 years
- Strong Net Present Value (NPV): 36.84M–68.43M PKR over 10 years (at a 10% discount rate)
- Attractive net gain: up to 358.8M PKR over a 25-year horizon
- Lower capital investment makes it feasible for small-scale private operators

Limitations

- Low operational margin: Despite steady revenue, the NEPRA tariff of PKR 39.7/kWh significantly erodes profits, limiting long-term scalability
- Grid reliability issues: susceptibility to load shedding, voltage fluctuations, and rising electricity prices
- Environmental concerns: A fossil-fuel-dominated grid powered this model, limiting its contribution to emission reduction goals

This model is most appropriate for dense urban areas with relatively stable grid infrastructure, where civil works can be executed efficiently and demand is consistently high. However, because of its dependency on costly and unstable grid power, it offers limited flexibility and may become less competitive as clean energy alternatives mature.

Scenario 2: Solar-Only Model – Zero Operational Cost, Limited Coverage

With an upfront cost of 46.4 million PKR, this model uses solar energy exclusively. It provides 100% profit margin, as it bypasses grid energy costs, resulting in a daily profit of 26,400–39,600 PKR.

Advantages

- Zero fuel or energy cost after installation
- 100% profit margin; every kWh sold translates into revenue
- Long-term sustainability: minimal maintenance and stable energy input

Limitations

- Limited daily energy output (60% of grid capacity): ~240–360 kWh/day
- Longer payback period: 3.21–4.82 years
- High capital investment without corresponding full-day coverage

Despite lower daily output, this model is ideal for locations with limited or unreliable grid access, such as peri-urban or semi-rural zones. It also allows the owner to adjust the price downward to attract more users, since there are no recurring energy expenses.

Scenario 3: Solar + Battery Model – Highest Gains, Most Resilient

This is the most capital-intensive model, with a total investment of 61.05 million PKR, including solar panels and a 280kWh battery bank. However, it offers the most comprehensive energy solution, combining solar generation with energy storage.

Advantages

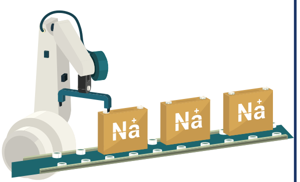
- Full utilization of demand potential (400–600 kWh/day)
- 100% profit margin since no grid electricity is used
- Highest long-term profits: Net gain of up to 541.2M PKR over 25 years
- Operational flexibility: Charging stations can operate at night or during cloudy days using stored solar energy
- Better service reliability: charging is uninterrupted even during peak grid load or outages

Limitations

- High initial capital requirement
- Slightly longer payback than grid-only, but shorter than solar-only: 2.53 to 3.80 years

This model is especially suited for national highways, intercity routes, and logistics corridors where grid access is limited or unreliable. Highway locations often face land availability but limited grid infrastructure—conditions ideal for solar installations and battery-backed charging. The ability to operate fully off-grid makes this model the most resilient and dependable solution for long-distance EV travel, fleet operations, and heavy-use commercial vehicles. Furthermore, with consistent traffic flow and higher per-day energy consumption, solar + battery charging stations along highways ensure quicker return on investment and long-term cost savings.

For a detailed financial and strategic comparison, see Table 7: Executive Summary of EV Charging Infrastructure Models in Pakistan in the annex. This table outlines key differences across grid-only, solar-only, and solar-plus-battery configurations to support investor and policymaker decision-making.



Solar + Sodium-Ion Battery Model: Cost-Effective, Resilient & Locally Anchored

As Pakistan expands its electric vehicle (EV) ecosystem, there is an urgent need for charging infrastructure that is cost-effective, scalable, and independent of fragile grid conditions. Scenario 4 presents a compelling solution by combining on-site solar generation with a 280-kWh sodium-ion battery bank, delivering a resilient and fully off-grid charging model.

Unlike traditional lithium-ion systems, sodium-ion batteries leverage domestic resources such as rock salt and agricultural biomass, making them more affordable, geopolitically secure, and better suited for Pakistan's climate and industrial capacity. With an initial investment of PKR 58.3 million, this model supports the daily charging demand of 400–600 kWh, enabling the full operation of a 240 kW EV charging hub.

The combination of solar PV (280 kW) and sodium-ion storage (280 kWh) ensures that the station can operate day and night, regardless of grid outages or solar variability. This flexibility is especially critical in remote or highway locations where grid access is weak, unreliable, or absent.

Capital Cost Breakdown

Component	Cost (PKR)
EV Chargers (240 kW total)	18.2 million
Solar PV Installation (280 kW)	28.2 million
Sodium-Ion Battery Bank (280 kWh)	**11.9 million**
Total Investment	**58.3 million**

From a financial standpoint, the system offers exceptional returns. With a 100% profit margin (no grid purchase required), the model generates between PKR 16.06M and 24.09M in annual profit, achieving payback within 2.42 to 3.63 years.

Daily & Annual Revenue

Parameter	Low Estimate	High Estimate
Energy Sold (kWh/day)	400	600
Price per kWh (PKR)	110	110
Daily Revenue (PKR)	**44,000**	**66,000**
Annual Revenue (PKR)	**16.06M**	**24.09M**

Over the 25-year project life, the net gain exceeds PKR 540 million, making it the most profitable and sustainable business model among the compared scenarios.

Metric	Low Estimate	High Estimate
Yearly Profit (PKR)	16.06 million	24.09 million
10-Year Profit (gross)	160.6 million	240.9 million
Net Gain in 10 Years	**102.3M**	**182.6M**
25-Year Profit (gross)	401.5 million	602.25 million
Net Gain in 25 Years	**343.2M**	**543.95M**

Using the standard NPV formula:

Low Case (PKR 16.06M/year): NPV ≈ **PKR 39.9 million**

High Case (PKR 24.09M/year): NPV ≈ **PKR 88.6 million**

Strategic Advantages

- 100% off-grid operation, eliminating NEPRA dependency
- Lowest battery cost per kWh using local sodium and biomass-based carbon
- Most climate-adaptive for Pakistan's high-temperature zones
- Highest long-term profitability of all models
- Supports local industry (SEZs, biomass, salt mines)
- Ideal for highway corridors, rural charging, and logistics hubs

In conclusion, this case isn't just a viable technical solution — it is a national strategy enabler. It aligns clean energy deployment with circular economy practices, industrial self-reliance, and mobility transformation. By adopting sodium-ion battery storage in solar-powered EV stations, Pakistan can pioneer a climate-smart and economically inclusive path toward electrified transport.

CHALLENGES RECOMMENDATIONS & CONCLUSION

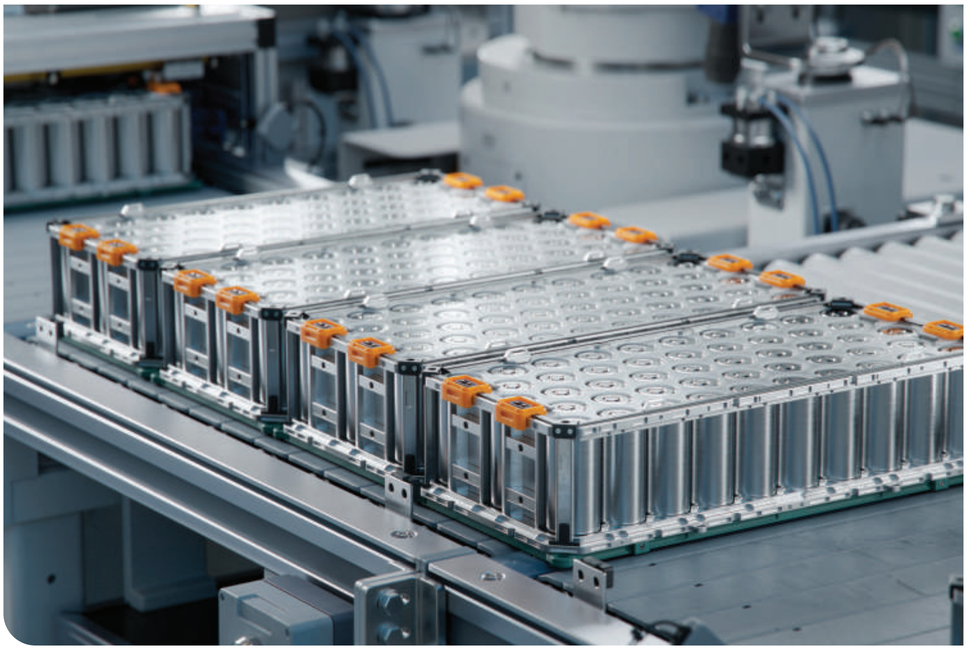
As Pakistan positions itself for an electric mobility transition, it must move beyond pilot projects and fragmented policy measures to implement a comprehensive, scalable, and resilient EV ecosystem. This study has outlined the technical, financial, and policy building blocks, ranging from distributed solar charging and Battery Energy Storage Systems (BESS) to localized vehicle manufacturing and innovative financing models. However, translating these insights into national impact requires overcoming structural challenges in affordability, infrastructure, manufacturing, and governance. The following section distills the key barriers facing Pakistan's EV transition and proposes actionable, phased policy recommendations to drive long-term, inclusive adoption.

8.1. CHALLENGE 1: HIGH UPFRONT COSTS AND LIMITED ACCESS TO FINANCING

Despite long-term operational savings, the high upfront cost of electric vehicles (EVs)—particularly for two- and three-wheelers that dominate Pakistan's transport fleet—remains a critical barrier. These costs are driven by imported components, limited local manufacturing, and an underdeveloped financing ecosystem. The absence of tailored loan products, subsidies, and risk-sharing mechanisms discourages adoption among low- and middle-income consumers, especially informal workers and gig economy participants.

Recommendations

- **Design and implement direct purchase subsidies for electric two- and three-wheelers**, focusing on affordability for low-income consumers, women, and commercial users (e.g., gig workers, delivery services). These subsidies should cover a substantial portion of the upfront cost (e.g., 25–35%) and be disbursed at the point of sale to reduce immediate financial barriers.
- **Establish green financing schemes under the State Bank of Pakistan (SBP)** that offer interest-free or low-interest loans for EV purchases, especially for motorcycles and rickshaws. Partner with microfinance institutions to make these loans accessible to informal sector workers and those without strong credit histories.
- **Introduce tax credits, reduced sales tax (GST), and waivers on registration and token taxes** for buyers of locally manufactured EVs. These fiscal incentives should be progressive—offering greater benefits to first-time buyers, owners, and small business fleet operators—to enhance both economic and social inclusion.
- **Create a national EV credit guarantee facility with blended finance**, where the government shares the default risk on EV loans provided by banks and finTech lenders. This would encourage private financial institutions to develop innovative products like lease-to-own, battery-as-a-service, or usage-based financing models.
- **Provide targeted fiscal relief to local EV assemblers**, such as duty-free import of critical components like battery cells and motors, as well as income tax holidays for new EV production units. These incentives will help bring down the cost of locally assembled vehicles and ensure long-term price competitiveness with ICE vehicles.
- Encourage provincial governments to align their tax structures with federal EV promotion efforts by standardizing reduced registration fees, excise duties, and road taxes for EVs across all provinces to avoid fragmentation and consumer confusion.



Timeline	Relevant Actor / Stakeholder	Responsibility
Short-Term (1–2 Yrs)	MoF, SBP, MoIP	Roll out direct subsidies and green financing schemes for electric two- and three-wheelers. Develop implementation guidelines for loan distribution in partnership with banks.
	SBP, Commercial Banks, Microfinance Institutions	Launch tailored lending products with credit scoring tools for low-income borrowers and informal workers. Promote mobile-based applications and disbursement channels.
Medium-Term (3–5 Yrs)	MoF, FBR, MoIP, Provincial Excise Departments	Implement harmonized tax incentives, including income-adjusted EV tax credits, GST reductions, and provincial fee waivers for all qualifying electric vehicles.
	MoST, MoF, Financial Institutions	Set up a national EV credit guarantee fund to support lease-to-own and battery leasing models. Pilot these programs in urban centers with high EV usage potential.
Long-Term (5–10 Yrs)	MoIP, FBR, Local EV Manufacturers	Institutionalize fiscal relief measures for domestic EV manufacturers and establish a phased plan for achieving cost parity between EVs and ICE vehicles through localization.

8.2. CHALLENGE 2: INADEQUATE AND UNRELIABLE CHARGING INFRASTRUCTURE

One of the most critical barriers to widespread EV adoption in Pakistan is the lack of reliable, accessible, and scalable charging infrastructure. Most cities have only a few functional EV chargers, concentrated in major urban centers, leaving rural and semi-urban areas underserved. There is a lack of standardized charging protocols, limited availability of fast chargers, and no national strategy for public-private investment in charging networks. Range anxiety, uncertainty around charging availability, and inconsistent charging tariffs are major deterrents for potential EV buyers—especially commercial users who depend on uptime and reliability. Without urgent infrastructure development, even subsidized EVs will face adoption hurdles because of usability concerns.

Policy Recommendations

- **Offer capital subsidies and tax credits for setting up EV charging stations**, especially in underserved regions and along intercity highways. These should be extended to both public and private sector entities, with higher support for fast-charging infrastructure and solar-integrated stations.
- **Promote distributed renewable energy-based charging models**, such as solar-powered stations integrated with Battery Energy Storage Systems (BESS), particularly in areas with grid reliability issues. Provide incentives for hybrid and off-grid charging stations.
- **Facilitate private investment through public-private partnership (PPP) models**, offering long-term site leases at petrol stations, bus depots, and commercial hubs. Allow space leasing by CPOs with revenue-sharing mechanisms to incentivize adoption.
- **Mandate charging interface standardization**: Develop and enforce national standards for EV charging connectors and protocols. Mandate the adoption of the CCS2 interface for all new fast-charging installations to ensure interoperability across vehicle brands and reduce consumer confusion.
- **Subsidize civil and electrical installation costs**: Capital subsidy schemes for EV charging stations should explicitly cover high-cost components such as transformer installations, three-core wiring, site preparation, and structural upgrades. This will lower entry barriers for Charge Point Operators (CPOs), especially in peri-urban and highway locations.
- **Promote standardization around high-capacity fast chargers**: Endorse 240kW fast chargers as the national benchmark for intercity corridors and logistics hubs to future-proof the infrastructure and align with global EV trends.

Timeline	Relevant Actor / Stakeholder	Responsibility
Short-Term (1–2 Yrs)	MoF, MoE, Private Sector (CPOs, Oil Marketing Companies)	Provide capital subsidies and tax credits for establishing urban and intercity charging stations, prioritizing fast-charging infrastructure and solar-powered stations.
Medium-Term (3–5 Yrs)	NEPRA, DISCOs, MoE, MoST	Promote time-of-use pricing. Support grid upgrades and enable smart charging technologies to manage demand and reduce pressure on the grid.
	MoPDSI, CDA, Provincial Building Authorities	Amend urban planning and construction codes to mandate EV charging readiness in new residential and commercial developments.
Long-Term (5–10 Yrs)	MoE, MoST, EDB, Private Sector	Scale up renewable energy–powered and BESS-integrated charging networks in off-grid areas. Expand PPP models to highways, logistics hubs, and mass transit terminals.

8.3. CHALLENGE 3: ABSENCE OF A LOCAL EV MANUFACTURING ECOSYSTEM

Pakistan lacks the industrial backbone to manufacture EVs at scale, with limited local value addition in battery assembly, motors, or electronics. This results in a reliance on imports, exposure to currency shocks, and missed opportunities for job creation and innovation.

Policy Recommendations

- **Implement a phased localization roadmap for EV production**, starting with high-volume components such as battery packs, motors, and controllers for two- and three-wheelers. Set minimum local content thresholds for EV manufacturers receiving government support or incentives.
- **Establish special EV manufacturing zones** within Special Economic Zones (SEZs) offering tax holidays, subsidized utilities, and one-window facilitation for EV and battery manufacturers. Prioritize land allocation and infrastructure development for indigenous EV component suppliers.
- **Offer fiscal and regulatory incentives for battery localization**, including duty exemptions on raw materials (e.g., lithium, cobalt), VAT waivers on local battery assembly units, and R&D grants for battery technology innovation.
- **Promote joint ventures and technology transfer partnerships** between local firms and international EV manufacturers. Support these ventures with matched funding, patent licensing assistance, and protection of intellectual property rights.
- **Require OEM after-sales and technical presence**: Require Original Equipment Manufacturers (OEMs) participating in the Pakistani EV market to establish formal after-sales service networks, technical support centers, and local spare parts warehouses. Link EV import permissions or subsidy eligibility to minimum service delivery standards and regional coverage thresholds.

Timeline	Relevant Actor / Stakeholder	Responsibility
Short-Term (1–2 Yrs)	MoF, MoE, Private Sector (CPOs, Oil Marketing Companies)	Provide capital subsidies and tax credits for establishing urban and intercity charging stations, prioritizing fast-charging infrastructure and solar-powered stations.
Medium-Term (3–5 Yrs)	NEPRA, DISCOs, MoE, MoST	Promote time-of-use pricing. Support grid upgrades and enable smart charging technologies to manage demand and reduce pressure on the grid.
	MoPDSI, CDA, Provincial Building Authorities	Amend urban planning and construction codes to mandate EV charging readiness in new residential and commercial developments.
Long-Term (5–10 Yrs)	MoE, MoST, EDB, Private Sector	Scale up renewable energy–powered and BESS-integrated charging networks in off-grid areas. Expand PPP models to highways, logistics hubs, and mass transit terminals.

8.4.
CONCLUSION: THE CASE FOR A COHERENT AND INCLUSIVE EV TRANSITION

Pakistan's shift to electric mobility represents a transformative transition that extends beyond the technological upgrade. It represents a strategic opportunity to strengthen energy security, reduce urban air pollution, create green jobs, and move towards climate resilience. With the transport sector consuming over 40%of the nation's fossil fuels and contributing significantly to greenhouse gas emissions, electrification must be pursued as a national development priority.

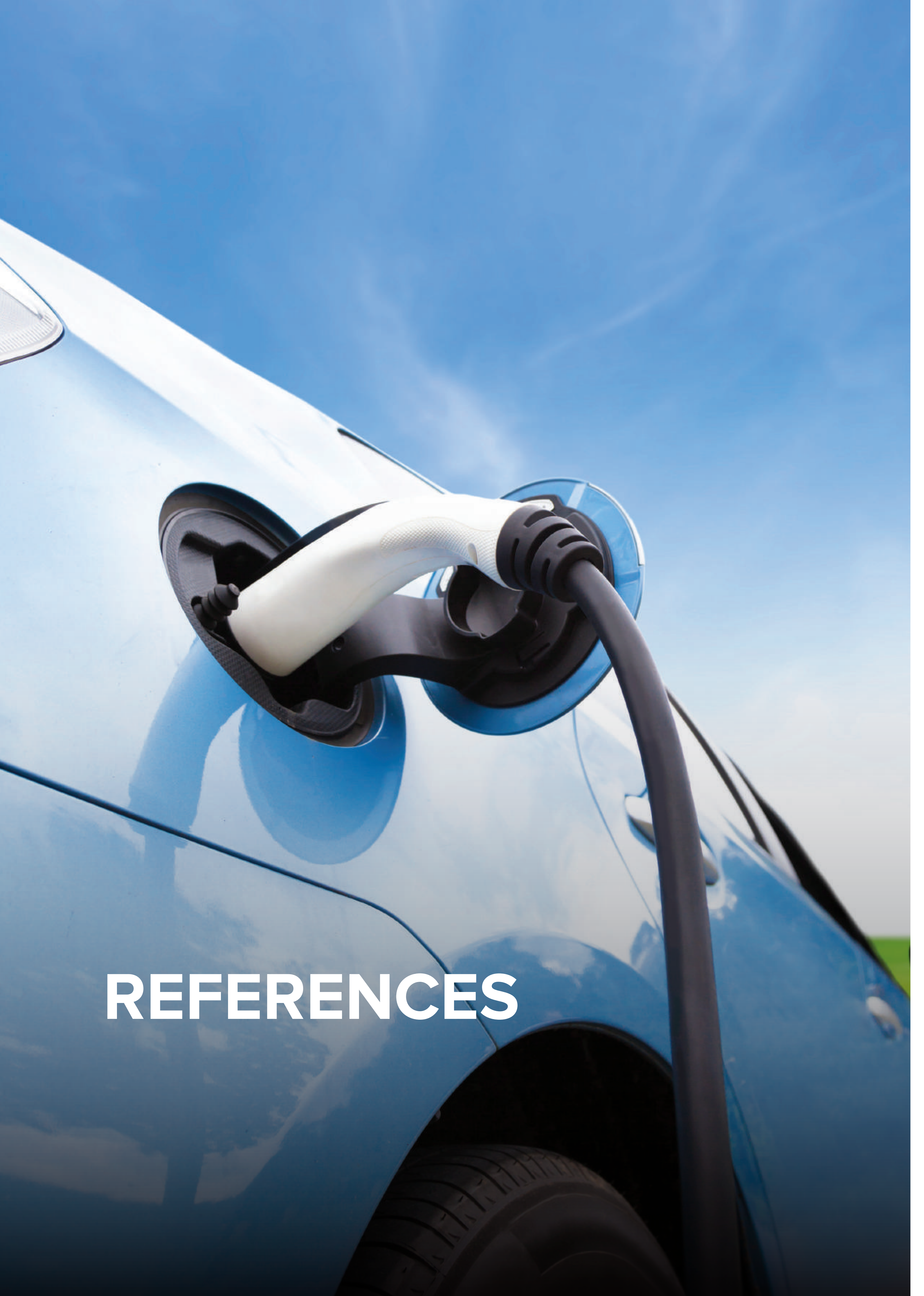
This study has highlighted that Pakistan's EV transition hinges not merely on vehicle adoption but on the creation of an integrated and bankable ecosystem. Smart charging infrastructure, especially solar-integrated battery hybrid solutions, stands at the core of this ecosystem, which offers the most cost-effective and resilient pathway for scaling electric mobility in Pakistan. Unlike grid-only models, which are vulnerable to rising energy tariffs and supply disruptions, solar-battery configurations offer zero operational energy costs, a predictable linear cost structure, and resilience in the face of grid instability. These systems not only reduce long-term risk for investors but also empower charge point operators to lower charging prices, thereby expanding access for both private and commercial users while preserving profitability. Such models are especially suited to high-demand use cases, including fleet operations, highway corridors, and peri-urban logistics hubs, where reliability and uptime are non-negotiable.

International case studies from Asia, Europe, and the United States affirm the viability of such decentralized charging models, particularly when supported by well-structured public-private investment frameworks. Alongside infrastructure, the electrification of two- and three-wheelers remains the most immediate opportunity for inclusive growth. These segments constitute the majority of Pakistan's vehicle fleet and are vital for urban and last-mile mobility. With targeted consumer subsidies, battery swapping infrastructure, and flexible credit tools such as lease-to-own models, the country can enable mass adoption at the bottom of the pyramid. Local manufacturing of these vehicle types, supported through fiscal incentives and phased localization, can further reduce costs and strengthen industrial capability.

The success of this transition will depend largely on the establishment of a robust and inclusive financing ecosystem. On the demand side, concessional loans, microcredit, credit guarantees, and finTech-enabled tools must be deployed to make EVs affordable and accessible, especially for low-income users and small business owners. On the infrastructure and supply side, a mix of blended finance instruments, green bonds, results-based funding, and concessional capital from international partners such as the Asian Development Bank and Green Climate Fund can de-risk investments and support large-scale rollout of solar-powered charging networks and domestic EV production.

A coherent national EV roadmap must now integrate these financing strategies as a core design feature. It should move beyond fragmented pilot projects and aim for coordinated investment, regulatory clarity, and institutional leadership. Public-private partnerships, fiscal reforms, and equitable access policies must be interwoven to ensure that EV adoption is not only technologically feasible but also economically and socially inclusive.

Pakistan stands at a crossroads. With the right mix of policy vision, financial innovation, and infrastructure scale-up, the country can lead a transformative shift toward clean and affordable mobility. The electric vehicle transition is no longer a future ambition; it is a present-day imperative,and the time to act decisively is now.



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Annex I

Region	Project/Initiative	Key Features	Energy Source	Impact	Financing Option
Asia	BluSmart's Renewable-Powered EV Fleet & Tata Power Solar-Powered Charging Hubs; Ceylon Electricity Board's EV Charging Stations; Shenzhen Battery Swapping and Smart Grid Solutions; Victorian Big Battery and EV Fast-Charging Network; Fastned's Solar-Powered Charging Stations	Includes a ride-sharing fleet powered by renewable energy, solar-powered EV charging hubs with battery storage, government-led EV charging stations, battery swapping technology to manage peak demand, and battery-buffered fast-charging stations ensuring stable power supply.	Solar, wind, battery storage, hydro, and battery swapping integrated with the grid.	Promotes sustainable urban mobility with affordable and stable power supply. Expands EV accessibility in cities and along highways while reducing reliance on fossil fuels. Enhances peak demand management and strengthens solar-powered EV infrastructure.	Private investment, government incentives, and public-private partnerships.
Europe	ElaadNL's Smart Charging Network; Gridserve's Electric Forecourts; Fastned and Grid-Integrated Charging Stations	Smart charging networks optimize renewable energy use, provide dedicated EV forecourts with ultra-fast charging and public amenities, and include grid-integrated charging stations with battery storage for uninterrupted charging.	Wind, solar, battery storage, and grid-integrated solutions.	Enhances grid stability, supports sustainability goals, and encourages EV adoption by offering reliable, fast-charging infrastructure. Ensures reliable charging even during grid instability.	Government and private investment, grid support, and public-private partnerships.
USA	Kansas City's Clean Charge Network & Sol-Ark's Off-Grid EV Charging Solutions	Large-scale charging network reduces range anxiety. Includes off-grid EV charging solutions using hybrid inverters.	Grid-connected charging with renewable integration, solar, and battery storage.	Encourages EV adoption by reducing range anxiety and offering scalable, cost-effective charging solutions.	Utility company investment, private investment, and cost-saving strategies.

Annex II - ESE FRAMEWORK FOR PAKISTAN – A MULTICRITERIA FRAMEWORK			
Key Factors	**Economic Impact**	**Social Impact**	**Environmental Impact**
Affordability & Cost of Ownership	EVs, especially two- and three-wheelers, offer lower operational and maintenance costs than ICE vehicles	Affordable EVs improve mobility for low- and middle-income individuals	Increased EV adoption reduces CO_2 emissions from transport.
Investment in EV Infrastructure	Development of charging stations and local manufacturing is crucial . BYD Pakistan plans to establish an assembly plant by 2026, aiming for 50% EV sales by 2030	- Improved infrastructure alleviates consumer concerns about EV usability.	Sustainable infrastructure enhances environmental benefits.
Job Creation and Industry Growth	Over 60 manufacturers are producing electric two- and three-wheelers in Pakistan	Transition to EVs creates jobs in manufacturing, battery production, and services	Growth in the EV sector fosters environmental awareness.
Impact on Trade Balance	EV adoption reduces fossil fuel imports, improving the trade deficit = - From July-April FY-2022, oil imports surged by 95.9% to $17 billion.	Reduced fuel imports stabilize domestic fuel prices.	Lower fossil fuel use decreases environmental degradation.
Accessibility & Mobility Improvements	Two- and three-wheelers provide an affordable transport option.	In Punjab, 90% of registered vehicles are motorcycles and rickshaws.	Electrification of public transport reduces urban air pollution.
Gender & Social Inclusion	EVs improve mobility options for women.	Increased mobility fosters social inclusion and economic participation.	Inclusive transport solutions promote equitable environmental benefits.
Reduction in Greenhouse Gas (GHG) Emissions	EVs lower CO_2 emissions from transport.	In 2021, Pakistan's transport sector emitted 51 million tonnes of CO_2.	Reduced emissions improve public health and mitigate climate change.
Air Quality Improvement	Transitioning to EVs reduces urban air pollution.	Pakistan ranks as the **5th most polluted** urban environment globally.	Improved air quality enhances quality of life and reduces disease risks.
Fuel Savings (PKR)	17,857M (Cars), 33,333M (2/3 Wheelers), 1,375M (Buses), 1,650M (Trucks)	Reduced fuel expenses for consumers and businesses.	Decreased fuel dependency reduces CO_2 emissions.
Idle Vehicle Fuel Savings (PKR)	4,286M (Cars), 6,667M (2/3 Wheelers), 611M (Buses), 578M (Trucks)	Energy-efficient EVs cut costs for individuals and businesses.	Lower energy wastage leads to fewer emissions.
Socio-Economic Cost of Emissions Avoided (PKR)	3,096M (Cars), 8,960M (2/3 Wheelers), 235M (Buses), 281M (Trucks)	Improved public health and reduced pollution-related illnesses.	Estimated **65% reduction in tailpipe emissions**.
Maintenance Cost Savings (PKR)	3,000M (Cars), 7,222M (2/3 Wheelers), 280M (Buses), 280M (Trucks)	EVs require fewer mechanical repairs, saving money.	Less oil and lubricant waste reduces pollution.
Total Yearly Economic Impact of EV Transition	**PKR 109.6 Billion (USD 0.81 Billion)**	**Potential Oil Import Reduction: USD 1.5-2 Billion Annually**	**Total CO_2 Reduction: 53 Million Tons Annually**

Annex III

Countries	Initial Challenge	Government Interventions	Outcome
Norway	High EV prices made them unaffordable for the average consumer.	**Tax Exemptions:** Norway implemented substantial tax incentives, including exemptions from value-added taxes (VAT) and registration taxes for all-electric vehicles. **Additional Benefits:** EV owners received perks such as free tolls, access to bus lanes, and reduced parking fees.	These measures significantly reduced the cost disparity between EVs and conventional cars, leading to a surge in EV adoption.
New Zealand	Limited EV adoption due to high upfront costs.	**Cash Rebates:** Introduced cash rebates for consumers purchasing EVs to make them more financially attractive	The financial incentives spurred increased EV sales, contributing to a growing presence of electric vehicles on New Zealand roads.
Indonesia	Low EV adoption rates due to affordability issues	**Purchase Subsidies:** Implemented EV purchase subsidies starting in 2023 to lower the cost for consumers. **VAT Discounts:** Offered value-added tax discounts on EV purchases, reducing the VAT rate from 11% to 1% for vehicles meeting local content requirements.	These incentives have made EVs more affordable, encouraging higher adoption rates among consumers.
France and Germany	High EV costs deterred lower-income consumers	**Purchase Incentives:** Both countries offered various tax and purchase incentives to reduce the financial burden on buyers. **Targeted Support:** Implemented programs specifically aimed at making EVs affordable for lower-income individuals.	These efforts have broadened the EV market, making electric cars accessible to a wider demographic.
India	High upfront costs and limited charging infrastructure hindered EV adoption.	**Incentive Programs: L**aunched the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, providing subsidies for EV purchases and supporting charging infrastructure development. **Tax Benefits:** Implemented reductions in Goods and Services Tax (GST) for EVs from 12% to 5% and offered income tax deductions on interest paid on loans for EV purchases.	These measures have led to increased EV sales, with electric vehicles comprising over 6% of India's vehicle market, avoiding 10 million tonnes of carbon emissions from 2020 to 2024
Thailand	High EV prices and limited consumer interest impeded adoption.	**Financial Incentives:** Provided subsidies of up to 150,000 baht per EV and reduced excise taxes to as low as 2%. **Investment Promotion:** Offered incentives to manufacturers, including tax holidays and import duty exemptions, to encourage local EV production.	These interventions increased EV registrations, with electric vehicles accounting for 17% of new car sales in 2023, up from 6% in 2022.

Annex IV			
Category	**Grid-Only Model**	**Solar-Only Model**	**Solar + Battery Model**
Business Viability	Short-term gains but limited resilience and rising operational risks	High-margin model with low running costs and scalable footprint	Most bankable long-term model with highest margin and flexibility
Initial Investment	Lowest (26.2M PKR)	Moderate (46.4M PKR)	Highest (61.05M PKR), offset by returns and resilience
Operating Cost	High (grid tariff at PKR 39.7/kWh)	Minimal (zero fuel cost)	Minimal (zero fuel cost, battery reduces demand volatility)
Revenue Predictability	Low: dependent on tariff hikes and grid outages	High: predictable due to self-generation	Very High: dispatchable stored energy ensures stability
Profit Margin	Lowest (~64%)	100% profit on energy sold	100% with potential for time-of-use pricing
Charging Price Flexibility	Low: constrained by grid pricing	High: can reduce tariffs and attract more users	Highest: price control with buffer for premium services
Energy Resilience	None: fully reliant on national grid	Moderate: limited during cloudy or night periods	High: operational even during outages
Best Suited For	Densely urban areas with highly reliable grid	Urban/peri-urban areas with sunlight access	Highways, logistics hubs, off-grid or load-shedding zones
Environmental Impact	High: grid-powered, fossil fuel heavy	Low: solar-powered, zero emissions	Lowest: clean, reliable, and independent
Policy Leverage	Minimal: fewer incentives available	Strong: eligible for solar subsidies and net metering	Very Strong: fits with climate finance and GCF mechanisms
Investor Suitability	Opportunistic, short-term ROI focus	Strategic investors with medium-term horizon	Visionary, impact-oriented investors with long-term goals

Policymakers and investors should prioritize Solar + Battery models, which offer the highest financial returns, resilience, and environmental value. While solar-only systems are highly profitable and more accessible, grid-only models present rising long-term risks due to energy price volatility, grid instability, and lack of climate alignment.

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Sarim Zia is a dedicated professional with a bachelor's degree from Quaid-e-Azam University and is currently pursuing a Master's in Economics at the National University of Sciences and Technology (NUST). With expertise in policy analysis, report writing, and stakeholder engagement, Sarim focuses on critical areas such as renewable energy transitions, energy efficiency, climate change, and sustainable development models. His work emphasizes creating innovative, evidence-based solutions to address Pakistan's energy and environmental challenges. Sarim's contributions to research and policy dialogues reflect his unwavering commitment to advancing sustainable practices and fostering resilient systems for a cleaner, greener future.

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