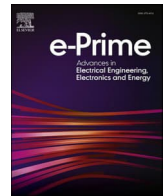




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## Electrification of Transportation: Policy Framework, Technical Aspects and Challenges in Pakistan - A Case Study

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### ABSTRACT

Pakistan faces severe air pollution and high dependency on imported fossil fuels for transportation, urgently needing solutions. Electrification of transportation could address these issues, but Pakistan lacks a clear roadmap for adopting electric vehicles. This paper examines the electrification of transportation in Pakistan, focusing on policies, technical aspects, and standards. It looks at best practices from developed countries and discusses incentives offered by the Pakistani government to boost electric vehicle adoption. The study also explores challenges and opportunities in adopting electric vehicles within existing power systems. A SWOT analysis is included, highlighting strengths, weaknesses, opportunities, and threats related to electric vehicle policies and market integration in Pakistan. By reviewing these factors, the paper provides insights into the obstacles and potential benefits of electric vehicle adoption. It also suggests ways for developing nations like Pakistan to encourage widespread use of electric vehicles, aiming to reduce fossil fuel dependency and meet environmental goals.

### 1. Introduction

Electric vehicle (EV) markets on a global and local scale are still in their early stages. There is a range of available technology options, including Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and hybrid electric vehicles (HEVs). Furthermore, advancements in Internal Combustion Engine Vehicles (ICEVs) are ongoing, e.g., energy recovery system technology is implemented by

many manufacturers [1].

Nevertheless, transportation electrification is regarded as the primary technological alternative as it offers number of additional advantages like reduced reliance on oil [2,3], improvement in compliance with environmental targets [4], smooth integration of alternative energy sources in the current power system [5,6], improve energy consumption efficiency [7], advance clean urban transportation infrastructure [8], reduced transportation expenses [9], and aid the power grid operation

*Abbreviations:* ADP, Automobile Development Policy; AIDP, Automotive Industry Development Policy; AIDEP, Auto Industry Development Export Plan; BEVs, Battery Electric Vehicles; CAGR, Compound Annual Growth Rate; CBU, Completely Built Units; CD, Custom Duty; CKD, Completely Knocked Down; CPEC, China-Pakistan Economic Corridor; DISCOs, Distribution Companies; EVs, Electric Vehicles; FCEVs, Fuel Cell Electric Vehicles; FFVs, Flexible Fuel Vehicles; G2Vs, Grid to Vehicles; GHGs, Green House Gases; GOP, Government of Pakistan; HCVs, Heavy Commercial Vehicles; HEVs, Hybrid Electric Vehicles; ICE, Internal Combustion Engine; ICEVs, Internal Combustion Engine Vehicles; NEVP, National Electric Vehicle Policy; NREL, National Renewable Energy Laboratory; OEM, Original Equipment Manufacturer; PAMA, Pakistan Automotive Manufacturers Association; PAAPAM, Pakistan Association of Auto parts and Accessories Manufacturers; PDMA, Provincial Disaster Management Authority; PHEVs, Plug-In Hybrid Electric Vehicle; PNNL, Pacific Northwest National Laboratory; PSQCA, Pakistan Standard and Quality Control Authority; SAE, Sustainable Energy Authority; SBP, State Bank of Pakistan; SWOT, Strengths, Weakness, Opportunities and Threats; V2B, Vehicle to Building; V2G, Vehicle to Grid.

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within a smart grid environment by utilizing various technical initiatives like Vehicle-to-Grid (V2G) [10], Vehicle-to-Building (V2B), and Grid-to-Vehicle (G2V) [11,12]. While V2G technology offers significant potential benefits, it also presents challenges, particularly in terms of battery degradation. Recent research has focused on developing advanced methods for parameter estimation and battery management in V2G systems to address these challenges [13]. While V2G technology offers significant benefits, it also presents challenges related to battery management and longevity. Recent research has focused on developing advanced monitoring systems to detect and manage in-cell variations in EV battery packs, which can be exacerbated by V2G operations [14]. These advancements are crucial for ensuring the long-term viability and reliability of EVs in V2G applications. Furthermore, electric vehicles can be integrated into energy markets through optimal bidding strategies. This integration allows wind energy portfolio managers to maximize profits while managing risks and considering market uncertainties [15]. The sophistication of these technologies enables a more advanced integration of EVs into the power system. This advanced integration facilitates the development of optimized bidding strategies for renewable energy portfolio managers. These strategies aim to maximize profits while managing risks associated with market uncertainties and the variability of renewable energy production [16]. The effective integration of EVs into energy markets and power systems is closely tied to advancements in energy storage technologies, which play a crucial role in addressing challenges related to grid stability, power quality, and supply reliability [17].

To develop the infrastructure and follow the growing global trends, numerous countries have allocated substantial resources and investments towards EV technology and infrastructure [18]. Given this perspective, it is crucial for Pakistan to thoroughly examine these issues for adapting to best practices in accordance with the local context and fit in electric mobility into the global movement. Currently, in Pakistan, only handful of companies are working on introducing HEVs and BEVs [19]. Similarly, electric bikes have gained traction in Pakistan, and few companies have introduced e-bike models for a variety of income levels. Private companies have established three BEV and PHEV charging stations in big city centers to sponsor the budding ecosystem of EVs like at emporium mall (Lahore), metro bus (Islamabad), and Dolmen mall (Karachi) [20]. However, these endeavors can only offer a few customers in specific regions only and thus cannot assist EV consumers on a large-scale. It shows that facilitation of this transition process through the implementation of efficient and cost-effective measures is necessary. One such measure is the development of all-in-one EV stations (AiOEVs) that can serve various types of EVs, including plug-in EVs, swappable EVs, and hydrogen fuel-cell EVs. These stations can integrate renewable energy sources like photovoltaic systems and employ optimized energy management strategies to enhance profitability and operational flexibility [21].

In this paper, an overview of the current situation of e-mobility in Pakistan is presented. The paper focuses on a brief description of the EV policy, challenges and opportunities for EV adaptation in context of Pakistan and SWOT analysis to evaluate the strength, weaknesses, opportunities, and threats is presented. The aim of this review is to provide the insights regarding the potential of EVs within Pakistan and to help policy makers and decision makers to allow and incentivize the deployment of EVs. It will not only help in reducing the GHG emissions but will also enhance the efficiency in transport sector. In Section 2 the electric transportation policy in Pakistan is discussed. Incentives provided by the government and existing standards of EV infrastructure in Pakistan are discussed in Section 3. The challenges for the deployment of EV are presented in Section 4. Opportunities for EVs in Pakistan are summarized in Section 5. Then, in Section 6, a SWOT analysis is developed and described. Finally, in the last section, the main conclusions are presented.

### 1.1. The current state of electric mobility around the globe

The global share of China and the United States, in electric four-wheelers is around 65 %, while Europe holds the second position with a market share of 23 % [18]. The EV market is most mature in Europe, where Norway leads the way with over 89 % of new car sales being EVs in 2022. China is also a major market for EVs, accounting for over 44 % of global sales in 2022. The United States is the third-largest market for EVs, with sales growing by over 96 % in 2022 [22]. The success of Norway is primarily associated with its eco-friendly policies that offer several incentives, tax reductions, and toll tax exemptions for electric four-wheelers on the road [23]. The other three countries are France, United Kingdom, and Japan.

In developing countries, except for China, the usage of EVs is not getting enough attention. The country with the second highest population, India, has less than a 1 % share of electric four-wheelers when overall car ownership in the country is considered [23,24]. The common perception of EVs is of electric four-wheelers, however, in many emerging countries such as Vietnam and China, a prodigious number of electric two-wheelers are sold [25,26]. Electric two-wheelers provide ease of travel and can be afforded at low prices, which translates into their staggering usage in emerging countries. China, as a global front-runner in the sale and usage of electric two-wheelers, sold more than 30 million units in 2018, and had a stock of 250 million units [27]. Following the steps of China, other Asian countries such as India, Vietnam and Taiwan are also increasing their market share for electric two-wheelers.

#### Fig. 1

To increase the usage of EVs in developing countries, it is important to consider the aptness of EVs with their electrical power structure. For this purpose, the power generation mix in developing countries was studied by the authors in [29]. The adoption of HEVs was suggested, noting that these countries predominantly have a thermal-based power generation mix, which offers higher energy and emissions savings with HEVs. In developing countries, considering the case of electric four-wheelers, the cost of ownership for common citizens is an important point of concern. Therefore, to promote EVs, in developing countries, electric two-wheelers can play an important role [30,31].

### 1.2. The context of Pakistan

Increasing vulnerability to climate change, growing financial deficit of the power sector and rapidly deteriorating economic outlook pose serious threats to Pakistan. The situation is not expected to improve in the upcoming years, unless significant measures are not taken to cope with these threats. To overcome the challenges presented by the aforementioned threats, a comprehensive strategy needs to be formulated and implemented.

Despite its contribution to global emissions is accounted for less than 1 %, Pakistan remains one of the most vulnerable countries due to its geographical location [32]. In Pakistan, the largest portion of Greenhouse Gas (GHG) emissions are due to the transport sector. By 2025, the total length of motorways is expected to increase by three times, and the total number of EVs are expected to be almost doubled, (i.e., currently from 19 million vehicles to 32 million vehicles) [33]. This ballooning of the transport sector will not only aggravate the already compromised situation of other sectors, it will also contribute to the increase of GHG emissions and further deplete the already endangered environment. Moreover, it will also significantly contribute to the overall socio-economic situation, where the transport sector will become a substantial burden on Pakistan's economy. This rapid growth in the transport sector is illustrated in Fig. 2, which shows the increase in the number of vehicles in Pakistan over time [34].

The power sector in Pakistan also faces extensive challenges. The energy mix of Pakistan is highly reliant on fossil fuels, where 80 % of electricity is produced using oil and gas. The high percentage of oil and



Fig. 1. 2030 Set targets for EV adoption and reduction in GHG emissions by world countries [28].

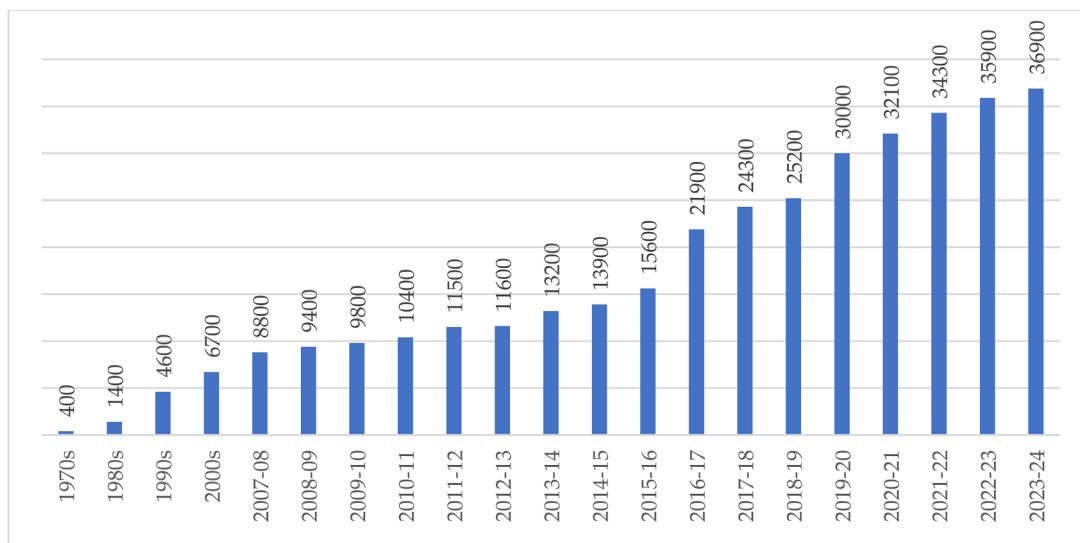


Fig. 2. Growth in transport sector of Pakistan (Thousands).

gas in the energy mix contributes to country’s problems at two fronts, i. e., it significantly increases GHG emissions and also results in high import fuel bill. The emissions can be reduced by increasing the percentage of renewable energy resources and distributed energy resources in the energy mix. It will not only reduce the import bill but will also help in producing clean green energy. Furthermore, according to Pakistan economic survey 2021–2022, the installed electricity generation capacity of the country stands at 41557 MW and the average demand for power is around 30000 MW [34]. Consequently, there is a

significant gap of MW of unutilized power exists, causing the financial deficit, as capacity charge payments are being made for these MW amount to billions of dollars. Such deficit significantly impacts the economic growth of the country.

Economic situation of Pakistan is deteriorating rapidly, mainly because of increasing trade deficit cause by increasing imports and declining exports. To meet the increased demand of vehicles and fuel, the import bill is expected to increase significantly, that will further worsen Pakistan’s economic condition. Currently, the fuel import bill for

Pakistan stands at 13.3 billion USD, and is estimated to reach 30.7 billion USD by 2025 [28]. Therefore, immediate measures should be taken to support the deteriorating economy and reducing the accelerating trade deficit.

To address these challenges, introducing EVs can be important. In the transport sector, using EVs will create a new industry in Pakistan. This will create many jobs and boost the country's economy. Also, EVs do not emit harmful pollutants because electric power is used instead of gasoline. Therefore, replacing Flexible Fuel Vehicles (FFVs) with EVs will help in reducing the emissions. EVs will also help solve some problems associated with power sector. EV commuters need to purchase electricity to charge their vehicle. This will allow government to sell unutilized power, in result, it can arrange the amount for capacity payments and generate revenue. Besides, EV will also reduce fuel import bill, subsequently decreasing the trade deficit. Considering this situation, the role of EVs in Pakistan's electricity market has become crucial and any further delays can have long-lasting impacts.

### 1.3. Scope and contribution of the review

This paper encompasses a comprehensive review of the current state of electric mobility in Pakistan. It examines the national electric vehicle policy and its implications, analyzes the technical aspects related to electric vehicle adoption in the Pakistani context, evaluates the challenges and opportunities for electric vehicle integration, and conducts a SWOT analysis to assess the strengths, weaknesses, opportunities, and threats for electric vehicles in the country. Table 1 summarizes the limitations of previous review papers on electric mobility in Pakistan and highlights the new insights provided by this paper. By synthesizing this information, this review aims to provide valuable insights for policymakers and decision-makers to facilitate and incentivize the deployment of electric vehicles in Pakistan. This work is particularly timely and relevant given Pakistan's unique economic, environmental, and energy challenges, and the potential for electric vehicles to address multiple issues simultaneously.

The main contribution of this paper is to provide a comprehensive review of the current state of electric mobility in Pakistan. This includes a detailed analysis of the country's EV policy, an examination of the challenges and opportunities for EV adoption within the Pakistani context, and a SWOT analysis to evaluate the strengths, weaknesses, opportunities, and threats related to EV implementation. By synthesizing this information, this review aims to offer valuable insights for policymakers and decision-makers to facilitate and incentivize the deployment of EVs in Pakistan. This work is particularly timely and relevant given Pakistan's unique economic, environmental, and energy challenges, and the potential for EVs to address multiple issues simultaneously.

### 1.4. Methodology and criteria

This review employed a systematic approach to identify and analyze relevant literature on electric vehicle adoption in Pakistan. Comprehensive searches were conducted in major academic databases. The search was primarily limited to English-language publications from 2017 to 2023 to ensure currency of information, with some seminal works from earlier years included for historical context. The review included peer-reviewed journal articles, conference proceedings, government policy documents, reports from reputable international organizations (e.g., IEA, World Bank), and industry whitepapers.

The collected information was synthesized using thematic analysis to identify key trends, challenges, and opportunities in EV adoption in Pakistan. A SWOT (Strengths, Weaknesses, Opportunities, Threats) framework was also employed to structure the analysis of Pakistan's EV landscape. To ensure the quality and relevance of included studies, each source was assessed based on its methodological rigor, relevance to the Pakistani context, and citation impact. Additionally, a comparative

**Table 1**  
Limitations of previous review papers on electric mobility in Pakistan.

Previous Review Papers	Limitations	New Insights in Your Paper
[35]	Focuses primarily on public intentions and behavioral factors affecting EV adoption. Limited analysis of policy implications and technical aspects.	Comprehensive review of national EV policy, technical aspects, challenges, opportunities, and SWOT analysis.
[36]	Provides a broad overview of EV market and policy but lacks detailed analysis of technical challenges and SWOT analysis specific to Pakistan.	Detailed analysis of technical aspects, challenges, opportunities, and SWOT analysis specific to Pakistan's context.
[37]	Limited to general recommendations for policymakers without in-depth analysis of Pakistan's unique economic, environmental, and energy challenges.	In-depth analysis of Pakistan's unique economic, environmental, and energy challenges, and how EVs can address these issues.
[38]	Comparative assessment with other countries but lacks focus on Pakistan-specific SWOT analysis and detailed policy implications.	Pakistan-specific SWOT analysis and detailed policy implications for EV adoption.
[39]	Focuses on global EV technologies and challenges, lacks specific insights into Pakistan's context.	Specific analysis of Pakistan's EV landscape, including policy, technical aspects, and SWOT analysis.
[40]	Detailed investigation of charging infrastructure and power management but lacks focus on Pakistan's unique challenges and opportunities.	Detailed analysis of Pakistan's EV policy, technical aspects, challenges, opportunities, and SWOT analysis.
[41]	Focuses on global EV adoption impacts, lacks specific insights into Pakistan's context.	Specific analysis of Pakistan's EV landscape, including policy, technical aspects, and SWOT analysis.
[42]	Focuses on consumer adoption factors, lacks detailed analysis of policy implications and technical aspects in Pakistan.	Comprehensive review of national EV policy, technical aspects, challenges, opportunities, and SWOT analysis.
[43]	Provides a broad overview of EV prospects in developing countries but lacks detailed analysis of Pakistan's unique challenges and opportunities.	In-depth analysis of Pakistan's unique economic, environmental, and energy challenges, and how EVs can address these issues.

analysis with EV adoption strategies in other developing countries was conducted to provide broader contextual insights.

This methodology allowed for a comprehensive mapping of the current state of EV adoption in Pakistan, identification of critical gaps in research and policy, and provision of evidence-based recommendations for stakeholders. By integrating diverse sources and analytical approaches, the review aimed to offer a holistic view of the challenges and opportunities facing EV adoption in Pakistan.

## 2. Electric transportation policy in Pakistan

The government of Pakistan (GOP), in 2021, approved its first National Electric Vehicles Policy (NEVP) to encourage the growth of EV market [44]. The policy sets ambitious targets for EV adoption, with the goal of having 30 % of all new passenger vehicles and heavy-duty trucks sold in Pakistan be electric by 2030, and 90 % by 2040. The policy also sets targets for the adoption of EVs in the two- and three-wheeler and bus segments, with the goal of having 50 % of new sales in these segments be electric by 2030 and 90 % by 2040 [44].

To achieve these targets, the NEVP provides a number of incentives for the purchase and use of EVs. These incentives include (1) reduced import duties on EVs and EV components (2) exemption from sales tax on EVs (3) provision of subsidies for the installation of charging stations

(4) provision of tax breaks for businesses that adopt EVs and (5) public awareness campaigns to promote the use of EVs.

The NEVP addresses vehicles (2/3-wheelers, trucks, and buses) as well as the relevant ecosystem for the aforementioned EVs. The policy focuses on a phased transition from the existing automotive industry to EVs that will ensure minimal loss to the existing automobile industry and its huge employment sectors. As a result, the policy strives towards the goal of a cleaner environment with initiatives being taken towards the local assembly of EVs at the initial stage. Moreover, the policy incentivizes both new and existing manufacturers of 2/3 vehicles, Heavy Commercial Vehicles (HCVs), and Automobile Development Policy (ADP) offering equal opportunity for all. The main aims of the policy include (1) Promoting industries to adopt EV manufacturing and create more jobs (2) Reducing GHG emissions by using green technology (3) Aiding in lowering the external deficit by reducing the share of oil imports.

### 2.1. Performance of the Pakistan transport sector

A considerable number (approximately 2.85 million) of 2/3-wheelers were manufactured in the fiscal year 2016–17, which increased to around 3.2 million in 2017–18, before a slight decline in 2018–19 (approximately 2.85 million). EVs will create a new market share and, along with that, take over the motor vehicle share to some extent. Motorcycles, rickshaws, and loaders have a greater scope in the market as their infrastructure is simpler than that of conventional vehicles, which might necessitate charging stations on motorways and highways.

The government has attempted to encourage competition in the automobile sector under the ADP [45]. The previous policy, the Automotive Industry Development Program (AIDP) 2007–2012, was developed with the intention of supporting the industry through 5-year tariff and other non-tariff plans. Owing to its localization compulsions, this policy failed to achieve its goals. As a result, the cabinet organized a high-level committee, which prepared the Automotive Development Policy (2016–21) with thorough engagement with all involved stakeholders. The new policy garnered much competition in the market, although it did not include 2/3 vehicles (motorcycles, rickshaws, and loaders), as these were covered by the continued tariff-based systems.

In Pakistan, there are two types of associations. The Pakistan Automotive Manufacturers Association (PAMA) represents automotive manufacturers. The industry locations are mainly Karachi, Lahore, and Gujranwala and include manufacturing products like plastic parts, batteries, vehicle interiors, rubber parts, and many more accessories. Meanwhile, the Pakistan Association of Auto Parts and Accessories Manufacturers (PAAPAM) represents the auto parts vendor sector, which includes around 3600 vendors, including 286 registered vendors (Tier I: 700, Tier II: 1300, Small and Cottage Units: 1300). The automobile vendor sector, which provides jobs to around 0.8 million people, is likely to be a crucial part of EV development in the common parts.

While the investment-heavy engine parts and other important parts are imported, Pakistan manufactures the body parts as well as the exteriors locally. Volume practically determines the localization of high-tech parts. Certain sectors, like motorcycles, have attained localization. Competent vendors for the production of common parts in Pakistan play a pivotal role in its transition to EVs. Although the maintenance cost is not a problem with EVs, the high battery replacement cost could discourage potential customers. However, this cost is anticipated to decrease eventually.

### 2.2. Limitations of the policy

As a developing country, Pakistan faces challenges in terms of underdeveloped roads and infrastructure, which can pose limitations in terms of providing targeted funding for EVs. To address these potential issues, it is crucial to establish effective coordination between the

government and stakeholders. This collaborative effort will help overcome obstacles and ensure a smooth implementation of EV initiatives in the country. Since there is no vehicle retirement policy in Pakistan [44], old vehicles are a major source of emissions. This contradicts the reduced emission objective of the policy. The use of hybrid vehicle technology has not been discussed in the given policy. Furthermore, the road infrastructure in Pakistan is poor, which is not suitable for advanced and low-weight EVs. The EV policy does not address this issue as well. No specific funding or subsidies for the import replacement through localization is discussed, which might reduce the cost of the specific EV parts in the future. In addition, due to Pakistan's underdeveloped conformity assessment framework, standardization, quality, and safety would be difficult. Besides, the most difficult problem is the lack of charging infrastructure. The investors in charging infrastructure and the amount of investment must be determined. Lastly, battery disposal must be taken care of due to its detrimental effects on human health. The aforementioned limitations are a major hindrance in successfully implementing the EV policy and adoption of EVs in Pakistan.

## 3. Incentives and standards of EV infrastructure in Pakistan

To support the initiatives for enhanced energy security and reduce GHG emissions, adoption of EVs is very crucial. To make EVs more affordable and to have a market acceptance, a sizeable market development effort is required along with incentives for EVs. This section discusses the recent policy incentives offered by government for EV infrastructure and standard to increase the EVs adaptability in masses.

The EVs are divided into different categories i.e., 2-, 3- and 4-wheelers, and depending on the development stages of each category at national and international markets, detailed policy incentives are provided for each category. In 2–3 wheelers segment, pure EVs have been proposed in the policy whereas, in 4-wheelers and heavy vehicles, advanced technologies like hybrid also exist. Moreover, batteries are an integral part of EVs and their development also requires incentives otherwise these will have to be imported at initial stage. Similarly, adequate charging infrastructure is also needed to eliminate anxiety amongst EV owners.

In addition to making EV more affordable, the effective charging infrastructure network is another fundamental part to enable further promotion and wider use of EVs across the country. The government incentives and technical standards of the charging infrastructure are discussed below.

### 3.1. Incentive for two, three and four-wheelers

#### 3.1.1. Incentives for two and three wheelers

In Pakistan, the transportation sector consists of various types of vehicles, including two-wheelers, three-wheelers, and four-wheelers. The popularity and usage of these vehicle types vary based on factors such as affordability, infrastructure, and regional preferences within Pakistan. Two and three-wheelers are the most commonly used mode of transportation. With the growing market for EVs in Pakistan, especially in urban areas, the use of two, three, and four-wheeler EVs is expected to increase significantly due to their low maintenance costs. To penetrate this market segment, it is proposed that EV-related parts be imported at a customs duty of 1 %, while the remaining body parts be imported according to the roadmap outlined in Table 2.

#### 3.1.2. Incentives for buses

All-electric buses can significantly reduce emissions and are best suited for fixed intra-city routes. However, these buses are expensive and require substantial incentives. Therefore, the following measures are proposed to encourage the use of all-electric buses:

Import all parts (both localized and non-localized) at a customs duty of 1 %, which is currently only applicable to non-localized parts.

Exempt all-electric buses from registration fees and annual taxes. To

**Table 2**  
Proposed custom duty (CD) structure for two, three and four wheelers in NEVP.

EV Type	Description	Category	Proposal
Two Wheelers, three wheelers	Motor, Battery and drivetrain (replacement of Engine/gear/ battery)	EV related	1 % CD
	CKD Non-Localized Parts	Non-EV	15 % CD
	CKD Localized Parts	Normal	46 % CD
	Sales tax	Locally manufactured	Fixed at 1 %
Buses/Trucks/ Prime Movers	CBU		50 % CD
	CKD Localized and non- localized parts		1 % CD
	Registration and annual tax		No fee or tax
	Hybrid Buses	EV	1 % CD
	Sales tax	Locally Manufactured	Fixed at 1 %
	CBU		50 % CD

Completely knocked-down (CKD) unit.

Completely built-up (CBU) unit.

make the purchase of EVs more convenient, financing schemes will be announced through the State Bank of Pakistan (SBP).

Consider electrifying the existing transport sector, particularly buses (metro buses and BRT routes) used in major cities of the country, on dedicated routes.

Under the ADP (2016–21), the CD on hybrid electric vehicles and buses is set at 1 %. However, due to a lack of infrastructure, no imports have been made in this category. This has also been extended to electric buses in CBU condition. Moreover, the sales tax on locally assembled buses will be 1 % at the point of sale, whereas at the import stage complete exemption from sales tax will be conferred.

### 3.1.3. Incentives for truck/prime movers

Heavy-duty trucks are required to perform transports across the country. For all-electric trucks, a widely distributed charging infrastructure will be required. Moreover, like buses, all-electric trucks are also expensive. To this end, the strategy required for trucks must ensure that the above-mentioned factors are considered. Keeping this in view, the GOP, having on board all relevant bodies, should employ the following measures.

In the coming years, electric trucks will be the most common intra-city freight carriers with a transportation capacity of 1 ton. The main aim behind this claim is the relative ease in the establishment of their charging infrastructure for the concerned authorities.

There will be no registration fee or annual token renewal charges for electric trucks. It is also possible that the State Bank of Pakistan to allow EVs purchase through initiatives like Green Banking guidelines as an incentive measure for the promotion of electrical trucks.

A 1 % CD applies to the import of all electric truck parts, whether localized or non-localized. This policy will stay in place until the AIDEP announcement. The 1 % CD clause was first proposed for HEVs in the ADP 2016–2021 policy framework. It was later extended to the electric trucks category and will continue until the new AIDEP announcement. The sales tax for localized electric trucks is 1 %, and the import of their parts will have a zero-sales tax policy.

The GOP intends to incentive localized designing and manufacturing of all components of EVs through the above-mentioned policies. The critical components of EVs includes batteries, motors etc. and their localized manufacturing comes down to the initiative of smaller components manufacturing in the initial phase. It becomes imperative to foster the local production of EV components in order to promote local manufacturing of EVs. Owing to current time limitations, the policy primarily focuses on initiatives to boost the adoption of EVs for now. The possibility of encouraging domestic component manufacturing can be explored in later stages, particularly considering challenges posed by

low import tariffs that hinder localization efforts.

### 3.2. Incentives for EV manufacturing and new investments

To encourage the local manufacturing and new investments, the government has taken several significant measures in given policy. Additionally, specific incentives have been proposed for the period spanning from 2021 to 2025. The General Sales Tax (GST) rate for EVs was brought down to 1 % of the prevailing rate and annual renewal fee for EVs was exempted completely. For facilitating the EV charging, the policy recommends incentivizing the power tariff on charging stations, however details of this incentive were not given. In addition, the EVs and hybrid vehicles were exempted from permit costs. The government also aims to provide leasing of EVs at favorable rates, with 5 % interest rate on loans for part manufacturing. Moreover, the five-year income tax exemption is also granted to auto part manufacturers of EVs and its related equipment.

In order to fulfill the objectives of the policy, encouragement of stakeholders to set up EV manufacturing facilities and introduce EVs, incentives for both exiting players/manufacturing units and new entrants have been proposed in NEVP, in addition to interventions for promotion of parts and components manufacturing for the local market and potential export at a later stage. The salient features of incentives for new investment includes 0 % CD and taxes in imports of machinery and equipment for EVs. Modifications of existing facility to EV technology will be allowed and facilitated by engineering development board. Moreover, for 200 EV units imported by a company, 50 % of the prevailing import duty will be exempted.

These policies are expected to play a crucial role in the successful integration of EVs into the Pakistani market while minimizing the concerns of key stakeholders, including manufacturers and consumers. This new policy aligns with the ADP 2016–2021, which has attracted significant investments that require safeguarding.

Presently, Pakistan lacks a comprehensive system for the registration of EVs. Traditional ICEVs and chassis-based EVs possess chassis numbers, but the absence of an engine necessitates the assignment of a unique motor number for registration purposes. To rectify this, the GOP, in collaboration with relevant bodies, intends to undertake the following actions:

1. EV registration categories will be determined based on the electric motor's power rating. However, in cases where no registration fee is applicable, such categorization may not be necessary. Registration authorities will formulate an appropriate mechanism to implement this.
2. Registration authorities will assign a special and easily distinguishable color and design for registration plates for EVs.

### 3.3. Standards development

The establishment of standards is a necessary and key step in advancing electric mobility. Standards are particularly required for vehicle safety and charging infrastructure [46]. The importance of standards in reducing investment risks for stakeholders involved in the transition to EVs in Pakistan is imperative. By developing standards in parallel with specific policy instruments, the industry can be better equipped to manage the transition and create a more stable environment for investment.

Currently there are no established standards for the charging station infrastructure and development of EVs in Pakistan [20]. However, the policy highlights the importance of developing standards and recommends that necessary steps be taken in development of these standards. As 2–3 wheelers are on the mandatory list of the Pakistan Standards and Quality Control Authority (PSQCA), it is required that the organization develop and ensure the enforcement of standards. In addition, PSQCA should also consider the World Forum for Harmonization of Vehicle

Regulations (WP 29) Regulations for 2–3 wheelers while developing the standards. In the case of HCVs, regulations can be implemented in a phased manner according to the plan for adopting the WP 29 regulations, which has already been initiated by the Engineering Development Board (EDB) with the WP 29 Secretariat. Moreover, the AIDC or the National Standards Committee of the PSQCA are responsible for analyzing and recommending the adoption of the international standards such as United Nations Regulation (UNR) 136 for vehicle safety, UNR 100 for 4-wheelers or Chinese OEM Standards, EEC 134 for maximum speed for 2-wheelers and IEC 60335–2–29 for household chargers to ensure customer safety and that eradication of substandard products from the market.

### 3.4. Charging infrastructure for EVs

In order to increase the acceptance of EVs in the market, relevant authorities need to develop charging infrastructure in all major cities, fuel stations, commercial building and at important locations on highways. As per NEVP, at initial stage, only selected cities (i.e. Karachi, Lahore, Rawalpindi/Islamabad, Faisalabad and Peshawar) will have charging infrastructure at selected locations, which, will then be expanded to other cities. The policy recommends that, within every 3km<sup>2</sup> at least one DC fast charger will be installed. In addition, along all motorways and highways, a fast charger will be installed within every 15–30 km range. Besides, there may also be option for standardized swappable battery facilities for certain appropriate categories of EVs at public charging stations.

To identify locations, considering the existing load on the feeders is important. Therefore, electric distribution companies (DISCOs) need to identify such areas considering the mentioned criteria. DISCOs also have the responsibility to remove any network constraints to facilitate the installation of charging stations. The policy recommends the incentivizing of existing fuel stations to establish charging infrastructure. Local government bodies are directed to facilitate the process. It is important to note that, the policy recommends that initially only 2 and 3 wheelers may be promoted for transitioning to EVs as their charging facilities are easier to develop.

## 4. Challenges for EVs in Pakistan

Adapting EVs can solve many problems for Pakistan. However, several challenges impede the large-scale adaptation of EVs. Integrating EVs with ICE automobiles can face many obstacles. Therefore, it is important for all stakeholders, such as the government, automobile manufacturers, and venture firms, to ensure a smooth transition. The government's policies are vital because these policies directly impact the industry. The effective policy for EV industry will encourage the manufacturers consumers and venture firms for complete compliance, in result, expedited EV integration can be achieved. Below key challenges for the integration of EVs in Pakistan are summarized.

### 4.1. Policymaking

Around the world, renewable and green power is required as FFW exhausts pose threats to the atmosphere and increases health risks. EVs being a major driver of green power or clean electricity, are widely used across the world. However, despite such precarious circumstances, Pakistan has not yet made the same devotion towards the development of EVs. Pakistan needs effective policies, and proper legislation for EV industry to promote the enforcement and adoption of this emerging technology. Some of the recommended policies, in context of Pakistan, are discussed here.

#### 4.1.1. Capital and tax subsidies

One of the major advantages EVs have over FFWs is their low running outlay compared to capital expenditures [47]. The current lack of

differentiation between the importation of CBU and CKD vehicle parts led to high duties and taxes on EVs. To reduce the cost of capital, the government should provide relief on CBU imports and support the localization and importation of CKD components for EV producers. Additionally, the government should reduce registration and token tax for EVs to promote their use as a substitute for traditional vehicles. The government should also build industrial areas and provide land permits for producers of energy goods for a period of 5–10 years. In 2019, the government approved a 50 % tax exemption for HEVs with engine capacity up to 1800 cc and 25 % for high-capacity cars with engine capacity between 1800 and 2500 cc [48].

To promote the adoption of EVs, the government need to establish exemptions for them through its governing bodies and provide high levels of assistance to attract both producers and consumers to this efficient technology. Many foreign countries offer subsidies and insurance on the purchase of EVs as a means to achieve climate change targets by reducing CO<sub>2</sub> emissions [49]. Government support can help increase the adoption of EVs by addressing market failures that may keep EV sales low. Financial incentives play a role in the transition to EVs and increasing consumer exposure to EVs can influence their purchasing decisions. As illustrated in Table 3. Many countries have implemented subsidies for EVs to encourage consumer adoption. The GOP proposed its first corporate strategy for transitioning the country to clean energy and to promote carbon-free green technology. It plans to purchase a significant number of EVs (100k) over a five-year period from various parts of the world [48]. The aim is to increase the adoption of EVs by converting almost 30 % of all vehicles to EVs by 2030. To achieve this, a 1 % general sales tax will be applied to the import of EV parts. This not only reduces CO<sub>2</sub> emissions but also saves at least Rs. 2 billion in fossil fuel costs that would otherwise burden the federal budget.

#### 4.1.2. Charging infrastructure policy

To increase the usage of EVs in Pakistan, it is crucial to invest in charging stations on highways, motorways, and local roads. This investment ensures easy accessibility and availability of these stations within realistic ranges.

The need for a reliable energy source without load shedding to minimize inconvenience for EVs users has been addressed in previous research [50]. To improve management, it is important to implement smart meters at each EV charging station to effectively control and monitor power levels and billing. To optimize usage of charging stations, it is beneficial to have multiple charging options available, such as slow and fast charging ports with varying charging rates. Slow charging options can offer lower rates for users without time constraints, while fast charging options using more energy can quickly recharge batteries for time-sensitive users. One major obstacle in expanding charging stations is the large investment required [51]. However, increasing the number of stations can be achieved through partnerships between public and private corporations in this field. Additionally, there are ways to minimize the overall cost of investment in charging stations [52]. Public-private partnerships in homes, offices, and malls can establish EV charging stations to provide better service to customers. Once there is a sufficient number of EVs on the market, charging network companies can become profitable, and initial costs can be subsidized by government agencies. It is important for the state to address major legislative and regulatory aspects related to EV charging stations [53].

To ensure consistency and safety, governments need to establish standards for EV charging devices. As there are currently no universally accepted specifications for EV charging devices [54], a standardized framework is vital for the design and configuration of EVs and their charging networks. Standards by Sustainable En such as SAE: J177229 and IEC: 6,219,630 have been proposed for implementing charging policies for EV charging facilities in various countries. However, the lack of accountability is not due to technical issues, but rather the absence of proper regulatory structures by internationally recognized bodies. Therefore, governments that aim to advance quickly in the EV market

**Table 3**  
Incentives by various countries for uptake of EVs.

Countries	Policies	Before 2019		2021		Type of Incentive
		PHEV (\$)	BEV (\$)	PHEV (\$)	BEV (\$)	
Austria	Klima: aktiv program (2007)	4500	All EVs	-	-	Subsidy on purchase
Belgium	Green Vehicle Incentive (2011)	Tax Reduction	Varying	0	0	Benefit on Tax
Canada	Electric Vehicle Incentive Program (2010)	1900	3800	4000	4000	Subsidy on purchase
China	New Energy Vehicles (2010)	1500	3700	1000	2400	Subsidy on purchase
France	Bonus-Malus (2007)	1000	9100	1200	7000	Subsidy on purchase
Germany	Green Car Incentive (2016)	3400	4600	7950	10600	Subsidy on purchase
Ireland	SEAI Grant Scheme (2011)	6500	6500	-	-	Subsidy on purchase
Italy	Eco-bonus Scheme (2019)	1800	4700	1800	4700	Subsidy on purchase
Japan	Green Vehicle Purchasing Promotion Measure (2009)	1700	3500	3850	7710	Tonnage and Acquisition for tax credit
Sweden	Super Green Car Rebate (2012)	2400	6500	2400	6900	Subsidy on purchase
Spain	Efficient Vehicle Incentive Program (2012)	0	6400	3200	6500	Subsidy on purchase
United Kingdom	Plugged-in Car Scheme (2011)	0	4500	-	2040	Subsidy on purchase
USA	Energy Improvement and Extension (2009)	7500	7500	7500	7500	Benefit on Tax

should create their own standards and policies.

To ensure effective deployment of EV charging infrastructure, policies for selling electricity and financing EV infrastructure is crucial. Local municipalities have an important role to play in regulation, public spending and offering subsidies to support the infrastructure. However, conflicting policies can negatively impact the development of charging infrastructure. Government intervention in energy purchases can also create confusion if charging service providers (including power utility companies) are controlled by government bodies. To address these issues, governments need to create policies to determine electricity selling prices and incentives for consumers who restore power to the grid. These policies are essential measures that should be taken to draft legislation [55].

To ensure the financial viability of charging network companies, governments need to authorize EV charging stations and provide opportunities for cheap electricity or discounts. Different lenders such as provincial and state bodies, corporate industries, or a combination of them can finance charging stations. A shortage of charging infrastructure and lack of fast-chargers has been found to negatively impact EV sales [56]. Therefore, charging facilities are necessary for EVs, with a charging station being a priority at home and accessibility at public spaces being the second priority. To address these issues, governments need to approve EV procurement plans and establish authorities for recovery from EV customers. OEMs, particularly in China and the US, are also looking for incentives in this sector. For example, Shenzhen provides EV buyers grants of up to RMB 20 K for vehicle insurance and charging infrastructure. Similarly, Los Angeles has an incentive of up to 2k dollars for home charging infrastructure for its first 5k customers. However, in Pakistan, vagueness in policies regarding power companies and federal aid for investment in charging infrastructure may serve as an obstacle for foreign investors. Therefore, governments are strongly suggested to issue policies to promote the adoption of EVs.

#### 4.1.3. Fiscal policy of EVs

One of the key strategies for enhancing technological advancements and bring down the initial cost of EVs is fiscal policies like excise duty or tax reductions. EVs in Pakistan has higher initial cost compared to traditional fuel-based vehicles [57]. High battery cost with its technological constraints are additional factors of higher cost of EVs in Pakistan. Table 4 shows the cost comparison of few vehicle types that are either manufactured or imported in Pakistan to confirm the disparities in prices of EVs in comparison to other vehicles. A number of countries are offering huge tax incentives already to boost the EVs purchase and consumption [58]. Chinese Foreign Ministry and taxation announced exemption of tax on the purchase of new EVs in 2008 [59]. Subsequently in 2009, 18-month relaxation period was announced for EVs buyers whose discount amount was further increased in 2010 to provide cover for higher class and engine capacity vehicles. US also set

**Table 4**  
Cost comparison of various vehicles in Pakistan.

Type	Brand	Model	Battery Type	Output Power (hp)	Mileage (Km/L)	Cost (million Pkr)
FFV	Toyota	Corolla 1.3	-	84	13	2.74
		Corolla Altis	-	120	14	3.14
		Honda Civic 1.8	-	141	14	3.65
	Suzuki	City 1.5	-	120	14.5	2.80
		Ciaz 1.4	-	91	14	2.30
		HEV	Toyota	Prius 1.8	Li-ion	121
Camry XLE	NiMH			176	22	7.12
RAV4				219	23	6.08
Honda	Freed 1.5			140	25	4.55
	Vezel 1.5			160	25	4.92
	PHEV		Honda Clarity		174	42
Hyundai		Ioniq 1.6		147	57	7.00
		Volvo S90T8		313	29	10.42
BEV	Lexus	RX 450h	NiMH	259	30	8.43
		Hyundai Kona-EV	Li-ion	201	118	7.41
	Tesla	Model X		518	99	14.39
		Model S		762	102	16.93
	Renault ZOE		134	105	10.31	
Chevrolet Bolt 5dr		200	108	6.78		

in motion the incentive scheme to promote PEVs purchase which resulted in sale of 200k EVs in that same year [60].

These policy changes helped China and the US to achieve their sales targets in a space of few years only. However, in Pakistan, no such steps were taken to reduce the purchase price of EVs. The only policy change is regarding the import of EVs, where only 1 % sales tax needs to be paid which is suitable for elite class and manufacturers only [60]. Such policies are not very encouraging for the government initiative of replacing fuel-based vehicles with EVs by 2025.

New EV strategy needs to be prepared by our government for equal distribution of fiscal benefits and strict regulation on following this strategy needs to be formulated and ensured. Several elements such as local manufacturers along with their business consolidators hesitate to follow the policy and strategy given by government. A significant portion of locally manufactured vehicles have Euro-II engines, which do not meet today's standards. Vehicle pricing in Pakistan is almost double compared to India. Therefore, the government must monitor the impact

of the EV policy on local manufacturers and ensure that these manufacturers do not undermine the implementation of the new EV policy. Few policy changes that can be introduced includes tax rebates, reduced charging rates and free highway travel for EV purchasers. Moreover, fiscal benefits for manufacturers and importers should be introduced to boost EV production. In Pakistan, ratio of imports to local manufacturing is 30–70 % according to PAMA. If locally manufactured batteries are used, it can bring down the overall cost to a large extent. If combined with lower charging prices, it can be a big boost for local users.

4.2. Research and development

Implementation of regulatory framework and promotion of R&D prospects will provide EVs a much-needed boost in Pakistan. Pakistan should firstly focus on highly trained skilled manpower in this filed to encourage investors and manufacturers. The recent engineering graduates are unable to cope with the latest advancement in technology currently. That’s why investing in establishing research sectors in battery management, transmission system etc. is very critical for all universities and related industries. The United States serves as an example where technological advancements are driven by specified research projects. These projects are funded and coordinated by the government, facilitating collaboration between industries and university research lab centers. In 2014, standardization efforts for various technologies were evident, as seen with the establishment of hydrogen fuel cell standards SAE J2601 and SAE J2799 [61]. Japan excelled in lithium-ion and fuel cell research by organizing joint research group of universities and industries in 2015 with government support. Similarly, Germany

established Innovation Enhancement framework of 4 key ministries to lead EV research and interact with leading industries and universities [62]. Pakistan can also follow this path by investing in R&D with collaborations with China, USA and Germany. Pakistan’s R&D necessities are highlighted in Fig. 3 accordingly.

Currently, Pakistan is facing sever challenges in coordinating with local industries and government organizations as most automation projects are being contracted out to third party foreign manufacturers. The best way forward is to connect government funded universities with local industries to emphasize and highlight EVs technology. This can lead to real world research projects for the students which can pave the way for technological advancements. The high training and research cost can be offset by relatively lower production costs which will keep the industries R&D programs flourishing. The technological exports from local industries can also help boast country’s economy. Hence, enhancing research in universities will lead to increased awareness and technological improvement in EVs sector.

4.3. Wide-scale installation of charging infrastructure

Broadening the scale of EV usage in a country may be the most challenging aspect as the huge electricity generation shortfall will shift the public confidence against EVs development very quickly [63,64]. A huge amount of financing is required for large scale installation of charging stations all over the country. Long-distance (inter-city) and short-distance (intra-city) are two major kinds of charging stations which are required. Long distance charging stations needs to be established on major highways and motorways within 100 kms to remove any

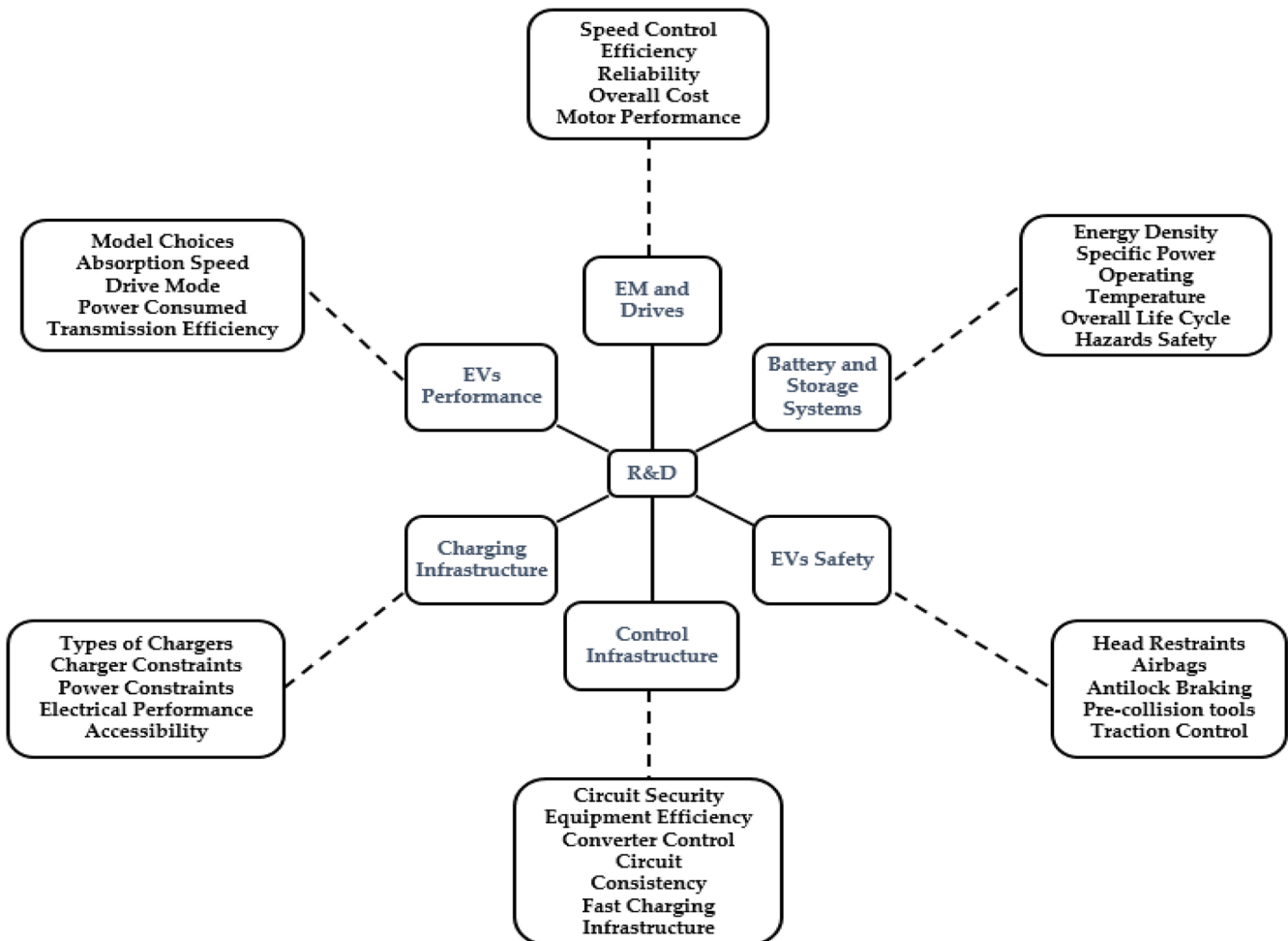


Fig. 3. R& D requirements for EV adaptation in Pakistan.

fears of EVs operational range. Short distance stations can be constructed on petrol pumps, shopping malls, residential settlements and public transport stations. Public-private partnership is the only viable solution or large-scale infrastructure deployment. Hence, it should be prioritized in policy making. EVs infrastructure key factors are as follows;

**Range anxiety:** Fear of getting stranded on highways with charging running out is a primary concern of consumers. This is a huge physiological barrier in EVs advancement. Therefore, charging stations should be optimally spaced and not based on full battery consumption studies [65]. Although, few charging stations won't be utilized much in this scenario, but it will help ease the physiological burden of the users. To overcome this issue this obstacle needs to be identified and actions needs to be taken to progress the evolution of EV transportation [66].

**Degree of convenience charging:** The comfort level of an EV owner to commercially charge EV rather than residential charging. The more residential charging point is utilized, the lower is the convenience level of the user. This will result in less investment for commercial charging points. If the convenience level is high, more commercial charging stations needs to be set up which will lead to huge increase in overall investment. Similar research showed that the installation of charging stations at office or travel destinations showed 71.7 % owners comfortably taking their EV for travelling [67].

**Adaptation rate:** The number of EVs in use or utilizing charging points shows the adjustment level. It is a proven fact that investors try to maximize their revenue whenever any commodity use surges. Pakistan has initially aimed at introducing 30 % EVs of the total vehicular load which will help the investors to have more confidence of revenue generation and invest heavily in EVs sector. Pakistan has also planned to install fast charging station in every 9km<sup>2</sup> intra-city are and in every 20 km of major highways and motorways. The basic question is how quickly users can switch to EVs with higher electricity penetration in energy markets. Government policies, technological progress and product development will be key factors in answering the above questions.

**Charging Choice:** A key point in the installation of charging infrastructure is the battery quality which will determine how much load it can take. The time it takes to charge an EV battery depends on the type of charger used and the initial state of charge of the battery [68]. Typically, charging stations have three options: slow, fast, and rapid charging. Slow charging typically takes the longest, while fast and rapid charging take less time but require specific equipment. The user is free to choose the charging method according to the requirement. The location of EV charging point has to be updated accordingly to charger's standard specifications along with the practical calculation of surrounding buildings etc.

#### 4.4. Grid load balancing

Grid load balancing is another critical issue for the current power system with exponential rise in EVs charging demands. Large scale electricity storage limitations make it key for reliable EV operation to match power generation and consumption at all times. Pacific Northwest National Laboratory (PNNL) has found out that US electricity grid can support 73 % PHEVs charging load which will be equal to 24 % of total energy produced. Rapid charging points also have a huge impact of local distribution system due to high energy demand (almost double than usual residential load). Power grid stability is seriously challenged due to several issues arising at the time of EV charging. Using thermal or coal-based power plant to supply energy for EV charging will lead to increased pollution and lowers the overall clean energy impact. A research study noticed that coal-powered EVs increases pollution by 17–27 % in comparison to the normal fuel vehicles [69]. Therefore, overall energy sector framework needs to be updated to make cleaner energy initiative equally useful. Also, the differences between energy generation and consumption can cause serious grid issues like power

quality issues, increased harmonics and transformer losses, line heating and reactive power consumption issues along with the apparent danger of harm to the grid structure. Hence, to utilize EVs evolution in a meaningful way, Pakistan needs to increase RESs share in the electricity generation and ensure coordinated EV charging at the charging points. The distribution system of Pakistan is considered flimsy which is highly dependent on climatic conditions coupled with poor line material and outdated grid infrastructure [70]. Therefore, Pakistan needs to be particularly aware of the challenges brought with sudden rise of EVs in the current power grid management structure. According to the new federal policy announced last year, 900k EV units are expected by 2030. It also aims to increase RES participation in energy generation to control CO<sub>2</sub> emissions as mentioned in 2030 Paris Accord. According to a study, overall energy requirements for EV charging is 1 GW [71]. By 2030, RES contribution in total power generation will be 15GW. This will be easily able to satisfy local energy demand and EVs charging demands.

The adoption of EVs in Pakistan is influenced by various factors such as policies and regulations, tax benefits and subsidies, availability of charging options and cost effectiveness in charging prices. Therefore, it is important to analyze the factors that influence a consumer's decision to purchase an EV. The impediments in the widespread adoption of EVs in Pakistan are listed in Table 5. These challenges are then prioritized based on their importance. The most crucial challenge is related to financial and technical barriers as the high cost of EV charging infrastructure is a major barrier to its development. A considerable investment is necessary to facilitate the transition to EVs, and the increased

**Table 5**  
Impediments in EV adoption in Pakistan.

Measure type	Challenge	Implementation Body	Priority
Financial	Tax Benefits and Subsidies to consumers	Federal and Provincial Government	High
Financial and Technical	Investment for the development of EV charging Infrastructure	Federal and Provincial Government	High
	Infrastructure Up gradation such as building, fuel stations and residential areas	Provincial Government	High
Financial and Technical	Energy generation cost	Federal Government	Medium
	Maintenance cost of Charging Stations	Federal and Provincial Government	High
Technical	Technical Skills acquisition	Federal Government	High
	Interface development from Grid to charging station	Federal Government	High
Technical and Public Awareness	Compatibility of charging stations with Utility standards	Provincial and Local Government	High
	Limitations of residential and commercial buildings, and fuel stations	Provincial and Local Government	Medium
Public Awareness and Education	Awareness regarding Cost effectiveness	Provincial and Local Government	High
	Reliability and Security concerns	Provincial and Local Government	High
Education and Regulatory	EVs installation and its ownership	Provincial and Local Government	Low
	Benefits for EV non-users	Provincial and Local Government	Medium
	Awareness regarding EVs technology	Provincial and Local Government	Low
	Public guidance regarding EVs	Federal, Provincial and Local Government	Medium
Regulatory and Technical	Lack of effective policies and procedures	Federal Government	High
	Incentives and facilities for research and development	Federal and Provincial Government	Medium

demand on national and local infrastructure presents additional technical difficulties. The development of charging infrastructure in rural areas, commercial buildings, and residential properties is also hindered by structural limitations and requires substantial resources. These financial and technological barriers can be addressed through collaboration between government and private entities. To promote the widespread adoption of EVs, incentive policies and rebate programs should be established by both federal and provincial governments, taking into consideration the needs of both consumers and manufacturers.

In addition to government efforts, partnerships and alliances can play a crucial role in addressing certain challenges particularly partnerships for initiative related to edification of public, as no monetary support or investments are required for them. It can help in disseminating the benefits of EVs such as low maintenance cost, less or no dependence on fuel, convenience and security to public and will promote the profitable purchasing of EVs. Moreover, it will also help in reducing carbon footprint by raising awareness about negative effects of GHG emissions.

## 5. Opportunities for EVs in Pakistan

The adoption of EVs is becoming increasingly popular as advancements in technology make it easier to upgrade automobiles and related systems, such as the power system. The transportation in coming future will mostly consist of EVs as it helps to increase efficiency, and reduce dependence on fossil fuels. The improvement in charging network and battery technology has convinced different stakeholders that EV adoption is beneficial for consumers and businesses. Keeping this in view, in this section, the opportunities linked with EV adaptations are discussed.

### 5.1. Economic development opportunity

EVs in Pakistan can bring a range of economic benefits, as economic development plays a vital role in improving human well-being across various aspects such as health, employment, education, and quality of life [72]. EVs can provide opportunities for economic prosperity in Pakistan, just as with any emerging technology. However, it is important to have a constructive and reliable strategy in place to manage the transitional consequences and optimize the advantages of integrated growth. The potential economic benefits of EV adoption in Pakistan are discussed in this section which includes, job creating in the EV manufacturing and charging infrastructure sectors, improved energy securing, enhanced power grid stability, reduced oil dependency and increased economic growth and development.

#### 5.1.1. Increased employment prospects

In Pakistan, despite education, widespread unemployment is a significant macroeconomic concern. The widespread acceptance of EVs would increase fresh and new employment opportunities, with manufacturers of batteries and chargers being the main job creators. The National Renewable Energy Laboratory (NREL) estimates that, for any country which is actively investing in the EV technologies, it can result in over 100,000 jobs per year in total [73]. Considering these estimates, the developing countries looking to incorporate EV technology in their industries, will need to arrange sufficient human resource for the emerging EV industry. Keeping this in view, in India, the primary developing skills and innovation department is working to develop a skilled, trained, educated, and technical workforce with profound technical knowledge and skills in a battery, distribution, selling and marketing, and EVs network design [74]. The shift towards EVs is likely to bring new job opportunities and economic benefits, as the majority of EV corporate industries have reported high levels of employee engagement, improved performance, and increased hiring. While the petroleum and refining sectors may see some job losses, analysis by the Australian Institute for Energy suggests that the transition to EVs could create twice as many new job opportunities as the loss of jobs in the

internal combustion engine (ICE) industry [75]. This means that the shift towards EVs is likely to have a positive impact on employment and economic growth in the long run. A comprehensive analysis of unemployment for Pakistan based on the NREL analysis is presented in Table 6. The analysis illustrates the unemployment percentage for both before and after considering NREL estimates of 100k jobs every year. The CEIC data is used to obtain the details regarding estimated population and rate of unemployment [76]. Therefore, to completely adopt to EVs technologies, all stakeholders including, the government, academic institutions, and industries will require to allocate sufficient resources for creating skilled and trained workforce to fulfill new employment demands.

#### 5.1.2. Enhanced living standard

EVs offer a range of benefits that can enhance the living standard, including environmental, economic, and personal. Like most other cars, EVs offer a range of features that can enhance the driving experience, such as flexibility, comfort, and security [77]. EVs often come with advanced technology and features such as regenerative braking systems [78], which can improve energy efficiency and lower the overall cost of ownership. These vehicles are very responsive, cost-effective, and affordable in terms of operation and maintenance costs compared to other vehicles (e.g., cars), due to having fewer moving parts. Moreover, EVs are generally more digitized and online connected than ICE vehicles, with the extra features of controlling the charging process through a mobile application. Having a variety of charging options for EVs is important for increasing the convenience and practicality of EVs. With the grid being nearly always available, charging can be done at various locations such as homes, offices, and on the road. This eliminates the need to frequently visit gasoline stations to recharge batteries. Additionally, in the UK, EVs have been found to have improved performance standards in areas such as initial speed, vibration, smoothness, reactivity, and ride comfort. These improvements in performance and convenience can make EVs an attractive option for many consumers, and contribute to enhance the living standard [79].

According to a survey, conducted by [80], most of the traffic accidents in Pakistan occur due to brake failures and mechanical faults. Another report unveils that the level of noise in Pakistan is in very high ranges due to the industrial machinery and increased traffic density [81]. Keeping this in view, the EVs with latest technology such as regenerative braking system can assist in reducing losses and less noise generating engines with batteries can enhance the mobility of pedestrians and drivers. Besides, the battery powered cars are safer than ICE cars as the elimination of front-engine decreased the risk of explosion. Therefore, taking all features into consideration, EVs have edge over ICE cars since it uses less energy while driving, which can lead to lower operating costs and a reduced environmental impact. Additionally, EVs offer a range of features that meet the needs of many customers, such as improved performance, comfort, and convenience, making them a more attractive option.

**Table 6**  
NREL Employment analysis of Pakistan.

Year	Population (mn)	Unemployment (%)	NREL Analysis	Unemployment after NREL Analysis
2017	205.170	5.832	0	5.832
2018	209.750	5.800	0	5.800
2019	213.950	6.000	0	6.000
2020	218.240	6.562	0	6.562
2021	222.590	6.300	0	6.300
2022	227.027	6.200	0	6.200
2023	231.552	7.000	0	7.000
2024	236.167	6.800	0.1	6.677
2025	240.875	6.600	0.1	6.457
2026	245.676	6.000	0.1	5.86
2027	250.573	5.500	0.1	5.351
2028	255.567	5.000	0.1	4.847

### 5.1.3. Reduce fossil fuels dependency

Pakistan is heavily dependent on imported crude oil and refined petroleum products to meet its domestic energy needs. In the fiscal year 2020–2021, Pakistan's import bill for crude oil and petroleum products was \$10.7 billion, which accounted for approximately 19 % of the country's total import bill [82]. Due to high-fluctuations in fuel rates at international market, the per annum cost of imports increases significantly, which in result, has severe ramifications on the electricity and transport sectors. The majority of the imported petroleum products in Pakistan are used for the transport sector, which includes the consumption of gasoline, diesel, and other fuels by cars, trucks, buses, and other vehicles. Out of \$10.7 billion, the share of petroleum products imported for the transport sector was 39.3 %, and the share imported for power generation was 20.7 % [82]. Fig. 4 predicts that, by 2030, the petroleum consumption will mostly be done by transport and energy sectors.

Many countries have reduced their reliance on fossil fuel through migration to EV technology. For example, China sponsored EV technology and manufacturing to overcome noise pollution, oil dependency, and to promote the high-tech industry [84]. Simultaneously, other countries such as Canada and New Zealand also reduced their reliance on fossil fuels and increased the uptake of EVs. As a result, these countries have achieved heightened energy security along with economic benefits [85,86].

Pakistan will meet intense challenges in subsequent times with threefold inflation in fuel prices, environmental pollution, and productivity charges. Therefore, adapting to EVs will certainly diminish dependency on imported oil and improve Pakistan's economy, which is crucial for the country. It is expected that the shift to EVs can nearly recover 25 to 40 % of imported fuel, although EVs are charged by fossil fuel sources such as gas and coal. Besides, EVs also are having substantial benefits because of less servicing and maintenance requirements and don't need changing oil and other lubricants that additionally mitigate the dependence on imported fuels. A recent study has assessed that EV adoption will result into significant load growth on Pakistan's energy mix but it would also significantly reduce the fuel import bill and support the Pakistan economy [87]. These actions would alleviate burden over state budget caused by oil import that can be employed to mature another sector; consequently, the widespread adaptation of EVs will substantially reshape the transport and energy sector in the next few years in Pakistan.

## 5.2. Environmental sustainability opportunity

Environment sustainability is one of the most important aspects of

reducing the concerns of international community about climate change [88]. With the technological and social developments, the human contribution towards overall GHG emissions has also increase significantly and it mainly comes from the energy supply, transport and manufacturing industries. The transport sector in Pakistan is also playing a significant role in worsening the environmental situation of country, provided that many major cities have been listed as one of the world's most heavily polluted areas.

According to the latest PPG analysis, Pakistan is one of the ten nations most impacted by global warming, where the mean temperature is anticipated to rise faster than in any other nation [89]. In 2015, the Provincial Disaster Management Authority (PDMA) projected that the heatwave caused approximately 1200 civilian deaths nationally, and 65,000 people required extensive medical attention. Furthermore, as shown in Fig. 5, Pakistan GHG emissions are expected to increase to nearly 80 MTCO<sub>2e</sub>, in result more passengers as well as cargo cars would pollute the roads in the upcoming years.

In response to its growing GHG footprint, Pakistan asserted in the Paris Agreement that GHG emissions will be reduced by about 20 % by 2030, indicating that the country will need to allocate \$7 to \$14 billion annually [91]. Until then, Pakistan had allocated about 6 % of its national expenditure to public transit and electricity generation. As a result, in order to address the issue of GHG emissions and reduce budget reliance, it is crucial to transition to a more sustainable transportation system. Numerous countries around the world have incorporated long-term mitigation techniques to accomplish their sustainability objectives, such as substituting ICE-based vehicles with EVs.

The statistics show that approximately half of GHG emissions from EV life cycles are connected to the manufacturing stage, with the manufacturing of battery accounting for 36 to 42 percent, followed by an electric motor accounting for 8 percent [92]. The above implications vary marginally due to a variety of factors including such battery design, inventory, model construction, and production [93]. After accounting for the effect of the development phases, the GHG emissions of EVs are 29 % less than gasoline vehicles and 20 % less than diesel vehicles. It is important to note that if coal or thermal power plants are used to power EVs, not only the carbon footprint will increase but the impact of energy transition will also be diminished. Natural gas-powered automobiles will emit 12 percent lesser emissions than ICE but coal-based energy sources are more likely to result in a 17 to 27 % rise in GHG emissions.

In order to combat the consequences of GHG emissions as well as provide economical mobility for all customers, the GOP recently approved an EV policy. By 2025, the main objective is to convert 30 % of all cars, trucks, and rickshaws to EVs, lowering GHG emissions. Although these aims may enhance specific sustainability objectives, a

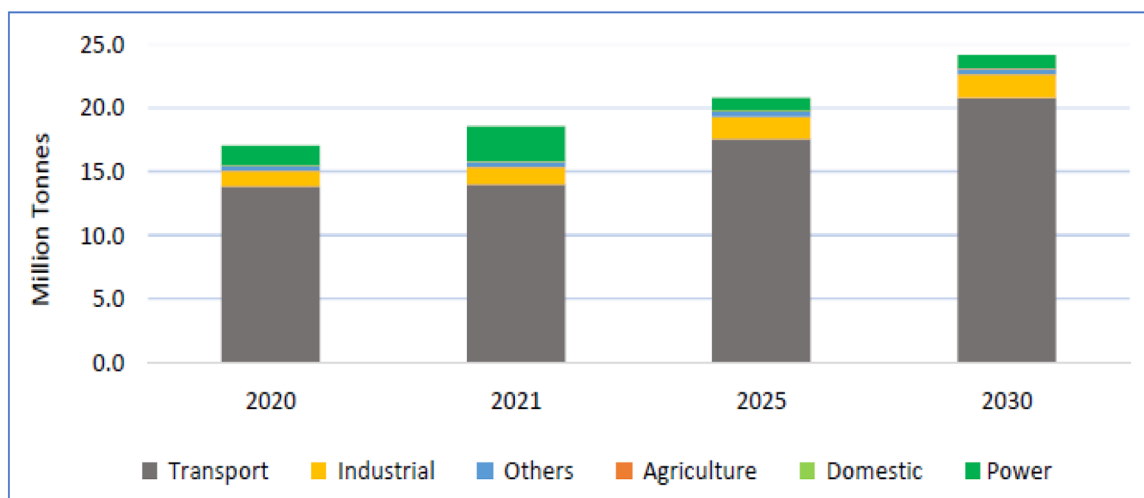


Fig. 4. Energy forecast for petroleum products [83].

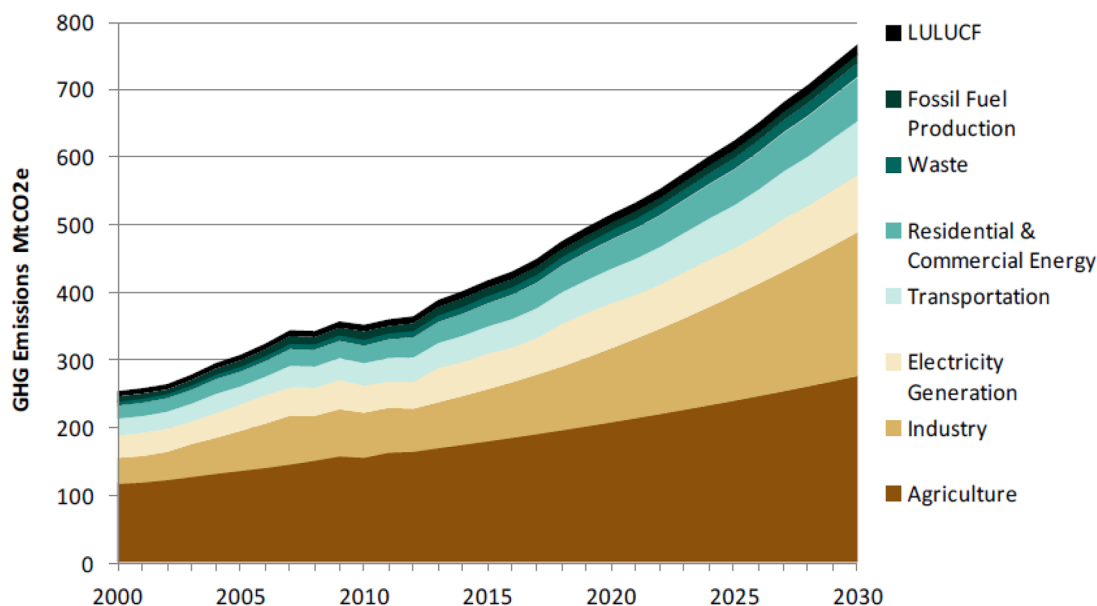


Fig. 5. The historical and the projected GHG emissions of Pakistan [90].

zero-emission network must be taken into account equally in the long-term strategy framework. The zero-emission technology averts severe health related problems, reduce GHG emissions and global warming, and, most importantly, reduces costs on climate change-related expenses. As a result, the government must concentrate on creating ICE emission solutions as well as carry out a complete analysis of EV emissions from various industries, such as battery charge sources and the manufacture of raw materials, including recycling, throughout the transition to EVs.

### 5.3. Opportunity for industrial development

Industry is viewed as the foundation of economic development in a region since it fosters the development of new technologies, lowers inflation and unemployment, and increases exports. The nations with the most advanced manufacturing capabilities, the most cutting-edge technology, and natural resources are at the top of the export food chain. China has undergone exponential expansion in recent decades, reducing hurdles to a major economic slump and making it into a worldwide manufacturing and export powerhouse [94]. Germany is expanding its manufacturing capacity as a consequence of executing Industry 4.0, a policy that positions the country as the greatest consumer and supplier of technical innovation in the newly globalized world. The second-largest contributor to the national economy in Pakistan is the after-service manufacturing sector, which expanded by 5.80 percent by 2018 contrasted with 5.43 percent last year [95]. Among the several industrial sectors, Pakistan's automotive industry is one of the quickest to grow, with a 7.2 percent Compound Annual Growth Rate (CAGR) in the Asia-Pacific region, and is anticipated to reach \$11.42 billion by 2025 [34]. Due to different taxes and penalties, the car industry added 12 billion rupees to the GDP and 30 billion rupees to the national treasuries despite the recent fall in sales. Nonetheless, Pakistan's car sector still heavily relies on ICE vehicles, many of which are decades-old models that are still in use today, despite the fact that emerging nations have adopted zero-emission technologies. Many developing nations, including Norway, have declared that FFV sales will cease entirely in the Netherlands by 2025, as opposed to comparable plans for 2030 [96]. The transit and automobile sectors have implemented emerging technology policies in all of those nations, providing significant prospects for both financial as well as technological progress.

The adoption of EVs on Pakistan's roads would open up a new

market, produce a range of jobs, and significantly contribute to the expansion of the industrial sector. Before the introduction of EVs, improvements were only related to products, but today manufacturers have experienced significant production modifications and efficient technological structures. There will be huge potential for both current and potential competitors as EVs adopt a variety of production techniques, which begins to overhaul the whole production chain. Besides emerging technological advances, a broad supply chain will also spread throughout the full competitive line in numerous industries, including transportation, retail, IT, telecommunications, oil, chemicals, and mining. When GOP made its announcement, the top manufacturing business in the world, Toyota, and the Chinese company BYD agreed to collaborate on the development of EVs in Pakistan [97]. The China-Pakistan Economic Corridor (CPEC) also serves as a driving force behind the integration of increasing foreign participation, notably in the manufacturing as well as technology sectors. As a result, Pakistan has a tremendous opportunity to expand its present industrial structure in the EV transition. To further enhance high-tech manufacturing, productive factories are to be frequently sponsored by research organizations and tax subsidies. A relationship between the government, business, academia, and non-commercial research institutes is required for the resource-constrained expansion of technologically sophisticated enterprises, in addition to encouraging universities to share industrialization knowledge. The automotive industry also has an obligation to stand up to Pakistan's global economic growth rivalry, through rapidly changing production capabilities. The transition of Pakistan from ICE to EVs would strengthen Pakistan economy, allow introduction of different vehicle markets and will also offer competitive and cost-effective markets for car manufacturers.

## 6. SWOT analysis

SWOT analysis is a tool to identify the crucial factors important to achieving an objective [98]. To perform SWOT analysis for assessing the viability of EVs in Pakistan, different aspects were taken into consideration. The SWOT analysis is developed and summarized in Table 7 taking into consideration several crucial aspects and factors. These factors include the examination of the market conditions in Pakistan, including consumer demand and existing infrastructure. Economic factors such as upfront costs, operating expenses, and potential cost savings were carefully analyzed. The analysis also reviewed the policies and

**Table 7**  
SWOT analysis.

Strengths	Priority	Weaknesses	Threats
<p><b>Government support:</b> The GOP has introduced an EV Policy that offers various incentives and subsidies to promote the use of EVs in the country, including tax exemptions, customs duties reduction, and income tax exemptions for local EV manufacturers.</p> <p><b>Low operating costs:</b> EVs have lower operating costs than gasoline-powered vehicles because these vehicles do not require gasoline. This absence of gasoline requirement can result in savings on fuel costs for drivers.</p> <p><b>Zero emissions:</b> EVs produce zero emissions, which can help to improve air quality. This is especially important in Pakistan, which has some of the worst air quality in the world.</p> <p><b>Potential to create jobs:</b> The EV industry is a growing industry, and it has the potential to create jobs in Pakistan. The government can help to create jobs in the EV industry by providing incentives to businesses that invest in EVs and by developing a skilled workforce.</p> <p><b>Increasing awareness:</b> There is a growing awareness among consumers about the benefits of EVs, including lower maintenance costs, reduced emissions, and</p>	<p><b>Reduced reliance on imported oil:</b> Pakistan imports a significant amount of oil, which is a major drain on the country's foreign exchange reserves. EVs can help Pakistan reduce its reliance on imported oil and save money.</p> <p><b>Improved air quality:</b> EVs produce zero emissions, which can help to improve air quality in Pakistan, which is currently among the worst in the world. Besides, it will also reduce the noise in the transport sector.</p> <p><b>Growing EV market:</b> The market for EVs in Pakistan is expected to grow at a CAGR of 29 % from 2021 to 2027, providing significant growth opportunities for local and international manufacturers.</p> <p><b>Charging infrastructure:</b> The establishment of charging infrastructure across the country is an opportunity for businesses to invest in the development and operation of charging stations.</p> <p><b>Export potential:</b> As the demand for EVs grows in Pakistan, there is an opportunity for local manufacturers to export their products to other countries in the region and beyond.</p>	<p><b>High upfront cost:</b> EVs are currently more expensive than gasoline-powered vehicles. This is a major barrier to adoption in Pakistan, where the average income is low.</p> <p><b>Lack of charging infrastructure:</b> Pakistan currently has a very limited charging infrastructure for EVs. This limited infrastructure is another major barrier to adoption, as potential buyers may hesitate to purchase an EV without certainty about charging locations.</p> <p><b>Need for government support:</b> The GOP needs to provide support for the development of the EV market. This can include providing incentives for the purchase of EVs, developing a charging infrastructure, and promoting the use of EVs.</p> <p><b>Low purchasing power of residents.</b></p>	<p><b>Competition from gasoline-powered vehicles:</b> Gasoline-powered vehicles remain the dominant form of transportation in Pakistan and will continue to be so for some time. This dominance means that EVs will face competition from these gasoline-powered vehicles.</p> <p><b>Lack of awareness about EVs:</b> Many people in Pakistan are not aware of EVs or their functioning. This lack of awareness can pose a barrier to adoption.</p> <p><b>Government policies that may not be supportive of EVs:</b> The GOP has not yet developed a comprehensive policy for EVs. This lack of a policy could create uncertainty for businesses and consumers, and it could make it difficult for the EV market to develop.</p> <p><b>Conservative approach:</b> by political agendas and end-users. Uncertainty of EV market future as standards are not well-defined, technical parameters are not addressed in detail.</p> <p><b>Lack of skilled workforce,</b> such as technicians and mechanics trained and skilled for EVs, as existing workforce is</p>

**Table 7 (continued)**

Strengths	Priority	Weaknesses	Threats
<p>fuel savings.</p> <p><b>Pilot projects:</b> The government has launched various pilot projects for the introduction of EVs in public transport, including electric buses in Lahore, Islamabad, and Karachi.</p> <p><b>Local manufacturing potential:</b> Pakistan has a well-established automotive industry that can potentially be leveraged to manufacture EVs locally. This would reduce the cost of EVs and create new jobs.</p>			<p>exclusively trained for ICEs.</p>

regulations related to EVs, including government incentives and support for charging infrastructure. Technological readiness, including the availability of charging infrastructure and battery technology, was taken into account. Environmental considerations, such as reduced carbon emissions, were assessed along with social acceptance factors like consumer attitudes and awareness. Industry and market trends, both globally and locally, were also analyzed. By considering these aspects, the SWOT analysis provides a comprehensive evaluation of the current state of EVs in Pakistan, highlighting the opportunities and challenges that lie ahead.

In terms of strengths, the analysis identified the growing awareness and concern for environmental issues, which creates a favorable environment for the adoption of EVs. Additionally, the decreasing costs of battery technology and the potential for energy independence were recognized as positive factors. Regarding weaknesses, the analysis highlighted the limited charging infrastructure in Pakistan, which poses a challenge for widespread adoption of EVs. The relatively higher upfront costs compared to conventional vehicles, along with concerns about range anxiety and battery life, were also identified as potential drawbacks. Opportunities identified in the analysis included the potential for government support and policy incentives to promote the adoption of EVs. The increasing global trends towards clean energy and sustainable transportation provide an opportunity for Pakistan to align with international standards and leverage technology transfer. The analysis also identified several threats. One of the main threats is the reliance on fossil fuels for electricity generation in Pakistan, which limits the environmental benefits of EVs. Inconsistent government policies and a lack of long-term planning for infrastructure development were identified as potential barriers. Additionally, the lack of public awareness and education about EVs and their benefits posed a challenge.

Overall, while there are several challenges to the development of the EV market in Pakistan, such as limited availability of EV models and the need for significant investment in charging infrastructure, The SWOT analysis provides insights into the strengths, weaknesses, opportunities, and threats associated with the viability of EVs in Pakistan. By addressing the weaknesses and threats while capitalizing on the strengths and opportunities, Pakistan can pave the way for a sustainable and successful EV ecosystem.

### 6.1. Disadvantages for Pakistan

The main problems for Pakistan in adopting EVs are mostly about money and infrastructure. EVs are very expensive to buy, which is a big issue in Pakistan where many people don't have a lot of money. Even if EVs might save money in the long run, most people can't afford them at first. This problem is made worse because there aren't many places to charge EVs in Pakistan. People worry about buying an EV because of uncertainty about charging locations. Also, regular gas-powered cars are much cheaper and more common, making it hard for EVs to compete.

Another big challenge is that many people in Pakistan don't know much about EVs. There's uncertainty about how EVs work or why using them might be beneficial. This lack of knowledge makes people less likely to want an EV. There's also a shortage of mechanics who know how to fix EVs, which could be a problem for EV owners. On top of this, the government hasn't made clear rules about EVs, which makes it hard for businesses to plan and invest in them. Some people in politics and the public are also slow to accept new ideas like EVs. All these issues together make it difficult for Pakistan to quickly start using more electric vehicles.

## 7. Conclusion

This review focuses on the analysis of the national EV policy and technical aspects related to EVs in Pakistan. A SWOT analysis was conducted to assess the strengths, weaknesses, opportunities, and threats associated with EV adoption in the country. The government has implemented an EV policy framework; however, it lacks clarity regarding investment in charging infrastructure and regulations needed to promote local manufacturing and assembly of EVs. To foster EV growth, it is crucial for the government to collaborate with the private sector and academia, creating an enabling environment. Clear guidance from policymakers is essential in this regard.

The SWOT analysis of the EV market in Pakistan reveals several aspects. Strengths include a skilled workforce, an emerging renewable energy sector, and a growing middle class interested in sustainable transportation. Weaknesses encompass limited charging infrastructure, high upfront costs, and the need for consumer awareness and education. Opportunities lie in utilizing renewable energy resources, promoting local EV manufacturing, and investing in research and development of EV technologies. Challenges involve addressing range anxiety, grid capacity, and integrating EVs into the existing transportation ecosystem. To fully realize the potential of EVs in Pakistan, a comprehensive approach is required. This entails consistent policy support, public-private partnerships, awareness campaigns, and capacity building. By addressing these opportunities and challenges, Pakistan can transition to a cleaner and more sustainable transportation system, contributing to a greener future. In conclusion, the viability of EVs in Pakistan hinges on the development of a robust EV policy that addresses the SWOT factors and fosters collaboration among stakeholders. Through concerted efforts, Pakistan can seize the opportunities presented by EVs while overcoming the challenges, paving the way for a greener and more sustainable transportation future.

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### CRedit authorship contribution statement

**Arsalan Masood:** Writing – original draft, Formal analysis. **Syed Zulqadar Hassan:** Writing – review & editing, Software. **Tariq Kamal:** Software, Resources. **Salman Khan:** Validation. **Syed Asad Abbas Rizvi:** Formal analysis. **Salman Salman:** Investigation, Formal analysis.

### Declaration of competing interest

The authors declare that there is no conflict of interest associated with the submission of this manuscript. They have no financial or personal relationships that could potentially bias the research or its interpretation. This declaration ensures the transparency and integrity of the work presented in the manuscript.

### Data availability

No data was used for the research described in the article.

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