Feasibility Study for the Electrification of Vehicles in Pakistan

Estudio de viabilidad para la electrificación de vehículos en Pakistán

Estudo de viabilidade para a eletrificação de veículos no Paquistão

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Summary. - Electric vehicles (EVs) have shown to be a viable alternative to fossil fuel vehicles (FFVs) in industrialized countries. The reason for the adoption of EVs in industrialized countries is that they outperform FFVs in terms of fuel usage, resulting in lower fuel imports, minimal environmental footprints, and less maintenance. The introduction of EVs in a developing country is a very demanding and challenging task. In this paper, the technical as well as economic aspects of introduction of EVs in Pakistan has been thoroughly explored. The statistical vehicle sale data for the past years has been considered to estimate the EVs requirement as per the Pakistan EV policy 2019. From the estimation, the electrical energy requirement to meet the policy targets has been calculated. From the calculated energy requirement, the details of charging infrastructure in major cities like Karachi, Islamabad, Lahore, etc. have been determined. It was found that EV charging station must be present for every 3x3 km radius. Further, from the estimated EVs, the cost saved by not using fossil fuels which should be required to run FFVs has been determined. It has been concluded from the economic perspective that EVs can significantly decrease the requirement of fossil fuel and can result in huge amount of cost saving by not using Fossil fuel.

Keywords: Electric Vehicles, Emissions, EV Policy, Oil Import, Pakistan.

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Resumen. - *Los vehículos eléctricos (VE) han demostrado ser una alternativa viable a los vehículos de combustibles fósiles (VCF) en los países industrializados. La razón de la adopción de VE en estos países radica en su menor consumo de combustible, lo que se traduce en menores importaciones de combustible, un impacto ambiental mínimo y un menor mantenimiento. La introducción de VE en un país en desarrollo representa un desafío considerable. En este trabajo, se analizan exhaustivamente los aspectos técnicos y económicos de la introducción de VE en Pakistán. Se han considerado los datos estadísticos de ventas de vehículos de los últimos años para estimar la necesidad de VE según la política de VE de Pakistán de 2019. A partir de esta estimación, se calculó la demanda de energía eléctrica para cumplir con los objetivos de la política. Con base en esta demanda energética calculada, se determinaron los detalles de la infraestructura de carga en las principales ciudades como Karachi, Islamabad y Lahore. Se concluyó que debe haber una estación de carga para VE cada 3x3 km. Además, a partir de la cantidad estimada de VE, se calculó el ahorro en costos derivado de la eliminación del uso de combustibles fósiles, necesarios para el funcionamiento de los VCF. Desde una perspectiva económica, se ha llegado a la conclusión de que los vehículos eléctricos pueden reducir significativamente la necesidad de combustibles fósiles y generar un enorme ahorro de costes al no utilizarlos.*

Palabras clave: *Vehículos eléctricos, emisiones, política de vehículos eléctricos, importación de petróleo, Pakistán.*

Resumo. - *Os veículos elétricos (VEs) têm se mostrado uma alternativa viável aos veículos movidos a combustíveis fósseis (VFCs) em países industrializados. A razão para a adoção de VEs nesses países é que eles superam os VFCs em termos de consumo de combustível, resultando em menores importações de combustível, menor impacto ambiental e menos manutenção. A introdução de VEs em um país em desenvolvimento é uma tarefa muito exigente e desafiadora. Neste artigo, os aspectos técnicos e econômicos da introdução de VEs no Paquistão foram explorados detalhadamente. Os dados estatísticos de vendas de veículos dos últimos anos foram considerados para estimar a demanda por VEs, conforme a política de VEs do Paquistão de 2019. A partir dessa estimativa, calculou-se a demanda de energia elétrica para atingir as metas da política. Com base na demanda de energia calculada, foram determinados os detalhes da infraestrutura de recarga em grandes cidades como Karachi, Islamabad, Lahore, etc. Constatou-se que uma estação de recarga para VEs deve estar presente a cada 3x3 km de raio. Além disso, a partir da estimativa de VEs, determinou-se a economia de custos resultante da não utilização de combustíveis fósseis, que seriam necessários para o funcionamento de VFCs. Do ponto de vista econômico, concluiu-se que os veículos elétricos podem diminuir significativamente a necessidade de combustíveis fósseis e resultar em uma enorme economia de custos ao não utilizar esses combustíveis.*

Palavras-chave: *Veículos elétricos, emissões, política para veículos elétricos, importação de petróleo, Paquistão.*

1. Background. - Global warming is damaging our planet at a very rapid rate. The driving force for global warming is carbon emissions. Around 43 billion tons carbon dioxide was produced through human activities in 2019 [1]. Due to these carbon emissions, Pakistan is facing lot of issues like higher air quality index, acid rains, etc. while Pakistan is the fifth most powerless nation in the face of climate change because it cannot control proficient climate change and relies on oil (petrol or diesel) primarily due to its easy availability and lower cost than other resources. Transport sector contributes around 24% in the global carbon emissions [2] due to dependence on fossil fuels which becomes the reason that many developed and undeveloped countries are planning to switch from Fossil Fuel-based Vehicles (FFVs) to EVs to reduce GHG emissions.

Currently, Pakistan's GHG emissions are growing by 6% per year, or 18.5 million tonnes of carbon dioxide (CO2) equivalent, in which the transport sector contributes around 22.69% of total annual GHG emissions [3] as can be seen in Figure 1. As a result, the best alternative solution is Electric Vehicles, which are gaining popularity and interest due to their advantages over conventional vehicles. The Pakistani government is also showing an interest in breaking into the market for electric vehicles in Pakistan. The government of Pakistan devised an "Electric Vehicles Policy" in 2019, which will aid in the adoption of EVs and have an impact on Pakistan's automotive industry growth, as well as help alleviate the country's massive debt burden. According to the government's policy handout, the target for EV adoption until 2030 is 30% of current vehicle sales [4], similar to other countries in the region.

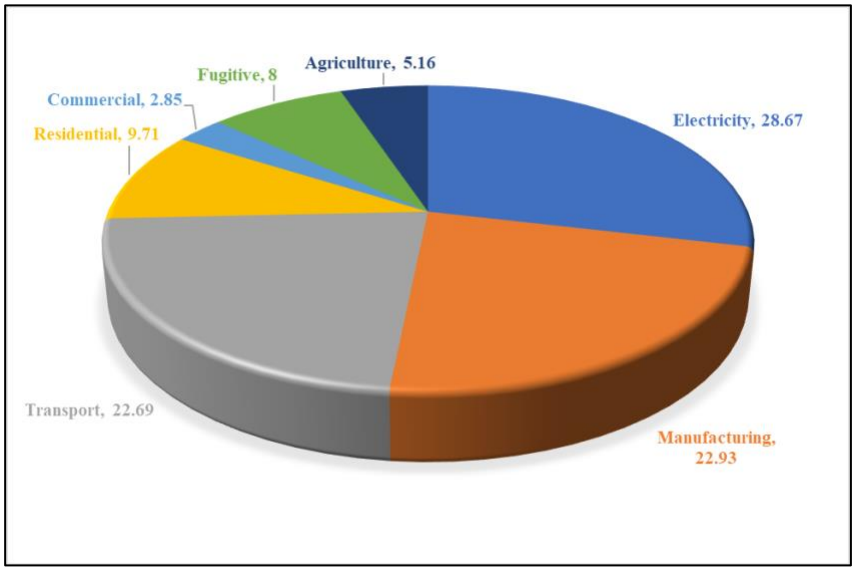

Figure I. Breakdown of GHG emission by sector [3]

1.1 Penetration of EVs in Developed countries. -

China: China is presently the world's largest oil importer. China's external oil dependence reached 70 percent in 2018 [5]. For China's energy security and environmental protection, limiting oil use is critical. The electric vehicle is often regarded as the most effective means of resolving these issues. Because of the development of electric vehicles, China's oil demand is expected to peak in 2029. Increased electric car penetration will boost economic production while also lowering nitrogen oxide emissions in China. Though carbon emissions will rise under the current power structure, the development of electric vehicles has the potential to significantly reduce CO2 emissions if non-fossil energy becomes the dominant energy source in the future in China [6].

European Countries: Europe, behind China, is the world's second-largest market for electric vehicles. The European electric vehicle (EV) market is expected to grow at an unprecedented rate by 2020.

More than 1.36 million new electric passenger cars, including battery-electric (BEV) and plug-in hybrid electric vehicles (PHEV), were sold in the region in 2019, up 143 percent from the previous year. Due to high sales, Europe surpassed China as the world's largest EV market in 2020. This occurred during a time when the automotive sector was through major instability [7].

EV sales in Europe climbed by 20% because of COVID-19, despite a 20% reduction in overall new car sales in Europe. The market share of electric vehicles has climbed to 11%. Several European markets have made significant progress. Greater percentages of new electric vehicle sales: 75% in Norway, 32% in Sweden, and 25% in the Netherlands and Finland has18%, Denmark has16%, Switzerland and Portugal has14%, Germany has13%, while France, Belgium, and the United Kingdom have 11% [8].

1.2 Penetration of Electric Vehicles in Pakistan's neighbouring countries. -

India: Electricity consumption in India has been increasing at a rate of 8–10 percent per year. The Indian government is actively promoting the use of electric vehicles in the Indian market. The National Electric Mobility Mission Plan (NEMMP) 2020 has been launched by the government of India to further evaluate their plans for the penetration of electric vehicles in their country [9]. The future analysis is done to determine the electric vehicle fleet, and then the future energy consumption per year is forecasted for 2030 using several scenarios of 20%, 30%, and 100% electrification of cars, as these targets are to be met by the Indian government. The results of a yearly cost-saving analysis for the researchers of India have discovered various types of automobiles, and they are as follows: There are four different categories of electric vehicles to consider: two-wheelers, three-wheelers, passenger vehicles, and commercial vehicles. It is believed that a two-wheeler travels 20 km per day, a three-wheeler travels 80 km per day, passenger vehicles travel 100 km per day, and commercial vehicles travel 250 km per day. The above part contains energy usage, which is used for further investigation. The charging unit cost of power is considered Rs. 5. The cost of fuel is calculated at Rs. 75 per litre. The cost-saving study is based on automobiles projected in 2030, with 100 percent electric vehicles being taken into account. As there will be around 4 million vehicles on the road in the future, there will be a significant increase in energy demand if they are all-electric [10].

India is a developing country, there is a pressing need to transition to electric vehicles as the gap between crude oil use and production widens. As India is a developing country, it is keener to adopt and penetrate the electrical vehicles in their country to evolve country to an industrialized and developed country. With these imperatives, electric vehicles would surely gain traction in India's future automobile market.

Bangladesh: Bangladesh is a country that is quite similar to our country and it is facing similar difficulties in the adoption of Electric Vehicles. EV adoption and penetration in Bangladesh becomes very challenging due to several barriers. Batteries run almost all the electric vehicles (i.e. bikes, auto-rickshaws, and electric bikes) in Bangladesh. A study showed that more than 0.5 million EVs are running in Bangladesh and these ingest 450 MW of electric power daily from the national grid [11], [12]. As the number of electric vehicles (EVs) grows, so does the demand for EV accessories and charging stations. According to the demand, the charging station, which is an important parameter, appears to be insufficient in Bangladesh. As a result, the electric car owner uses the residential rate to recharge the batteries in their home. In this sense, the power industry of Bangladesh has had a system failure, and a considerable quantity of revenue from this sector has been lost. In Bangladesh, there are no accurate statistics on EVs. As a result, the government is unable to take appropriate action in this matter. In Bangladesh, there are varieties of factors that influence EV adoption. Inadequate EV charging stations (EVCS), battery technology, power supply unavailability, excessive charging costs, pollution, and so on. So the study shows that Bangladesh is also facing the same barriers and difficulties to be feasible in the adoption of EVs [13]

1.3 Need of EVs in Pakistan. - In Pakistan, the transportation sector has experienced double-digit expansion. Almost the entire transportation sector is reliant on oil-based products, and the government spends nearly USD 13 billion annually on oil imports. The bill for oil imports is estimated to exceed USD 30 billion by 2025 if our transportation sector continues to grow at the same double-digit rate [14]. Pakistan's power sector has also suffered difficulties, with power generation failing to meet the country's power demand for the past decade. However, in the coming years, the situation will drastically deteriorate, and Pakistan will face a power-generating shortage. The country has already signed up for a new generation, according to the National Transmission and Dispatch Company (NTDC), bringing its overall power generation capacity to 41,981 MW peak generation [15]. In Pakistan, EVs will be able to take advantage of the power supply glut in the next years. After accounting for all transmission and distribution losses, we estimate that a daily supply of 1000 MW may fully charge about 500,000 EVs [16]. The installation of charging stations in every practical range on highways, motorways, and local roads is a significant consideration for capital expenditure in

charging stations for the expanding use of EVs in Pakistan. To improve governance, intelligent metering should be installed at each EV charging station to better control and monitor the power level while also providing an efficient payment system. To make the most of charging stations, more alternatives with multiple chargers, such as slow and rapid charging connections with variable charging rates, are necessary at each station. Users can make use of the benefits of slow charging ports at lower rates without having to rush; fast charging ports, which use more energy to replenish the battery and take less time to complete, will benefit hurried clients.

1.4 Challenges in the adoption of EVs. - Governments all around the world are encouraging users to switch from fossil-fuel vehicles to electric vehicles, but the technology still faces several serious challenges before becoming widely adopted. With 63 percent of consumers assuming that an EV is out of their budget, the capital cost has always been a big element in the EV purchasing decision [17]. With battery costs, declining and cost parity between EVs and ICE vehicles expected by 2026 [18], attention is turning to the problem of scaling the necessary infrastructure and raw material supply to enable mass adoption of EVs.

Charging stations are harder to find than traditional gas stations and are usually limited by investment costs and difficult infrastructure development. In addition, charging in places where you normally park, such as at home or work, presents unique challenges as this reduces the network of functioning charging stations and discourages consumers from switching to electric vehicles. Increased EV adoption adds to the pressure on the grid, which may necessitate new grid infrastructure investment to match the increased demand. As utilities and power companies try to figure out how to comprehend the quickly developing EV industry, forecasting when and where this electricity is needed is a new problem. Charging EVs at off-peak hours, such as late at night or early in the morning, reduces the danger of grid overload.

Grey energy networks, which rely heavily on fossil fuels, reduce the use of EVs as a means for businesses and consumers to reduce emissions. As a result, it is critical to decarbonize the grid as much as possible to persuade purchasers that switching to an EV is profitable and decreases carbon emissions [19]. EVs consume around six times the number of mineral inputs as ICE vehicles. According to the IEA (International Energy Agency), 70 million EVs on the road by 2040 would be followed by a 30-fold rise in mineral consumption [12]. There is no lack of these subsurface resources; the question is whether they will be harvested responsibly, by social responsibility governance, and in time to fulfill demand. It is expected that there would be a nickel scarcity and difficulties in scaling up lithium production. Because of the supply scarcity, producers may employ lower-quality mineral inputs, reducing battery performance [20].

Steps to allay these challenges: With the move to electric vehicles well underway, propelled by increased environmental concerns, government laws, and financial incentives, the obstacles created by this transformation are only mounting. Fortunately, AIoT-assisted technology (Artificial intelligence of things), when combined with other hardware, industrial, and supply chain solutions, allows us to overcome numerous problems. Battery monitoring, analytics, and recycling help to alleviate supply bottlenecks caused by increased demand for necessary battery materials by prolonging battery lifetime and reusability.

Smart and flexible charging technology utilizes idle power from car batteries to give additional electrical supply to the grid at times of high demand, in other circumstances, just intelligently stops, or decreases charging power. In contrast, it allows users to recharge during off-peak hours for one-third or less of the peak-hour charging price, lowering grid congestion and consumer costs during peak hours [21]. The charging system can better anticipate abrupt peaks in electricity consumption by allowing EV owners to plan to charge based on power limits, price, and priority, as well as sell unused power back to the grid.

On an integrated digital platform, energy management systems choreograph an energy system's generation assets (such as solar or wind power installations) and demand assets (such as EV chargers, heating and cooling systems, and lights). This enables real-time asset health and performance monitoring via the Internet of Things (IoT) connection and AI-driven algorithms, which maximize renewable energy consumption while lowering operating costs and system investments. It also enables the co-optimization of EVs and stationary storage with other grid-connected [19].

Exhaustion of Environment: Due to the effects of climate change, Pakistan has already been designated as the fifth most susceptible country [22]. Burning additional fossil fuels, including oil, will only exacerbate the problem. Pakistan's emissions are predicted to treble by 2020 and triple by 2030 [23], according to the National Economic and Environmental Development Study (NEEDS) study. Other harmful substances like sulphur dioxide (SO2), nitrogen dioxide (NO2), particulate matter (PM), PM10, and PM2.5, will also increase in the atmosphere because of increased fossil fuel combustion. Pakistan generates over 37% of its electricity from renewable sources [24].

When this is combined with the efficiency of EVs, environmental emissions are reduced by 70-80% when compared to FFVs. This indicates that, while electric vehicles have no particulate emissions, they have a 70-80% reduction in environmental emissions across the entire energy value chain [16]. Therefore, we can say that a step toward electric vehicles is the best solution to overcome the exhaustion of the environment in Pakistan.

1.5 Research Gap and Novelty. - From the preceding discussion, one can come with a conclusion that EVs is an attractive way to replace the fossil fuel-based transportation, to avoid the carbon emissions. But it is important to consider the technical requirements of the EVs for its implementation. In this research, the technical aspects of the EVs requirement have been thoroughly investigated. Moreover, the costing of the EVs including cost saved due to implementation of EVs have been discussed to investigate its economic aspects in Pakistan.

2. Methodology. - For the technical investigation, the immense amount of statistical data from different institutions in Pakistan is gathered. This section deals with the gathered data and information that are used in the prediction of vehicles by 2030, the number of electric vehicles, the energy required for these electric vehicles, the charging infrastructure required in motorways and major cities, the amount of oil barrels that can be saved from the penetration of electric vehicles and the cost saved from this EV penetration is discussed.

2.1. Prediction of Car Sales by 2030. - To predict the future number of vehicles that are going to be on the roads of Pakistan by 2030, the data is collected from registered vehicles of different categories from 2006 to 2019 and is presented in Table 1.

Year	2 wheelers	3 wheelers	4 wheelers	Cabs	buses	trucks
2006	137,892	6821	68610	1976	8779	9497
2007	144,081	12853	109053	1034	2999	3127
2008	175,768	11842	108006	2032	7796	8370
2009	1,089,538	33917	68487	16419	3627	5175
2010	1,476,832	64563	155213	1769	3686	8956
2011	1,718,229	56799	212729	19208	12898	15813
2012	1,669,346	57390	186794	1375	4973	6309
2013	1,836,893	85606	156652	190	4056	6377
2014	2,074,979	92929	277587	22254	4887	8271
2015	2,149,560	112289	218346	3081	6324	7626
2016	2,287,405	91673	262874	131	6580	8649
2017	2,278,212	80224	299039	227	7004	6829
2018	2,174,543	75709	207936	62	4741	3304
2019	736,248	20375	69318	52	839	6770

Table I. Vehicle sale over the year [25]

Prediction of EVs by 2030: For the Prediction of EVs in Pakistan by 2030, two different scenarios mentioned in Table 2 are considered that are according to medium-term targets and long-term targets of NEVP 2019 [4].

EV Penetration Targets	Medium-term targets (5 years)	Long-term targets (2030)
4 Wheelers (cars jeeps vans small busses)	100,000 EVs	30% of new sales
2 or 3 Wheelers	500,000 EVs	50% of new sales
Buses	1000 EVs	50% of new sales
Trucks	1000 EVs	30% of new sales

Table II. EV penetration targets [4]

Using the results from the calculations done for the prediction of sales of vehicles, the estimated number of EVs can be calculated for both scenario 1 and scenario 2

Charging Infrastructure: The calculation of the power requirement of EVs in Pakistan by 2030 for both scenarios 1 and 2 are done by the formula given below

$$E = N \times d \times e \qquad \text{Eq. 1}$$

Where,
E = Energy Consumed per day in kWh
N = Number of EVs
d = Average traveling distance in km
e = Energy consumption in kWh per km

Table 3 shows the average distance in km travelled by different categories of vehicles and their average energy consumption in kWh per km [26].

Vehicle Type	Average traveling distance in km	Energy consumption in kWh per km
2 and 3 Wheelers	20	0.0241
4 Wheelers	20	0.215
Buses	36	1.35
Trucks	100	1.242

Table III. Energy requirement by different EV [26]

According to the EV policy, there must be one DC fast charging station in every 3 by 3 km range in all the major cities like Karachi, Islamabad, Lahore, etc. So, 9 meter-sq is divided by the area of the city to get the amount of charging stations in that city [4].

$$\boldsymbol{Y} = \frac{\boldsymbol{A}}{\boldsymbol{9}} \qquad \text{Eq. 2}$$

Where,
Y = Number of charging stations
A = Area of city in meter-sq
Since, for the initial steps the policy aims at building charging infrastructure in the major cities that is why smaller cities are not considered. However, on motorways and highways, the policy suggests building a charging station every 15 km on all important motorways and highways.

Economic Analysis: Pakistan is a net importer of oil and its products. Beyond that, transport is the second largest user of energy after industry and accounts for about 34 percent of total final energy consumption and almost 59 percent of liquid fuel consumption in Pakistan. That is, air, sea, and road transport account for more than half of oil consumption (59 percent) followed by the power sector (32 percent) and industry (8 percent)

On average, the study finds growth of about 12.5 percent in the demand for petrol and about 9.6 percent in the demand for diesel in the road transport of Pakistan [14]. The number of barrels of oil extracted from the Pakistan economic survey is presented in Table 4 [27]

Years	Cost	M.T	Barrels of Oil
2010-11	8,761.50	N/A	N/A
2011-12	12,582.90	N/A	N/A
2012-13	12362.5	N/A	N/A
2013-14	12,221.10	N/A	N/A
2014-15	8,896.60	12,678,825	48,663,450
2015-16	5,584.80	11,241,367	7,053,648.25
2016-17	6,683.10	15,791,893	67,816,976.25
2017-18	8,393.30	19,223,622	19,106,751.5
2018-19	361.7	232,206	346,492
2019-20	6,417.30	13,521,203	9,968,162.75
2020-21	5,471.00	16,862,412	41,196,704

Table IV. Pakistan's Oil Import

Now talking about the benefit that the Introduction of EVs can make to the current situation of oil imports in Pakistan, we know that the transport sector is the biggest consumer of oil in Pakistan and accounts for 34 percent of energy consumption and 59 percent of the liquid fuel consumption
Using the average oil import cost and using the data from Scenario 1 and scenario 2 we can estimate the saved cost using the formula given below

$$\boldsymbol{Cost\ Saved} = (\boldsymbol{Average\ oil\ import\ cost\ X\ 0.34}) - (\boldsymbol{Average\ oil\ import\ cost\ X\ 0.34\ X\ Percentage\ of\ FFVs}) \quad \textit{Eq. (3)}$$

Here the factor (Average oil import cost X 0.34) represents the percentage of oil cost used in the transport sector.

3. Results and Discussions. - To study the trend of vehicle sales with respect to time, statistical software Minitab was utilized to create regression models for diverse vehicle categories. The sales statistics, as indicated in Table 1, underwent linear regression analysis to determine patterns over time. The findings in various vehicle categories are depicted in Figure 1. It is clear from the regression analysis that vehicle sales have been on a rising trend during the years. Various models were examined to find the best fit for each vehicle type. For two-wheelers, the linear regression model proved the most appropriate with an R-square value of 85.69%. This signifies that the model is able to forecast two-wheeler sales with about 85.69% accuracy and has a margin of error of 14%. The high correlation indicates a consistent pattern of growth in two-wheeler sales over time. For four-wheelers, the best-fitting model was found to be the quadratic regression model with an R-square of 68.71%. This relatively lower R-square indicates that the quadratic model does not forecast four-wheeler sales with great accuracy. The precision of this model is less than that of the linear model for two-wheelers, which means that other factors besides time contribute a great deal to four-wheeler sales, which makes the sales fluctuate to a point that it cannot be fully accounted for by a plain time-based model. In the case of three-wheelers, the linear regression model proved to be suitable, as was the case for two-wheelers. Although the model has decent predictive power, there is some error involved, which indicates that other factors affecting the trend must be taken into account in order to make a more precise forecast.

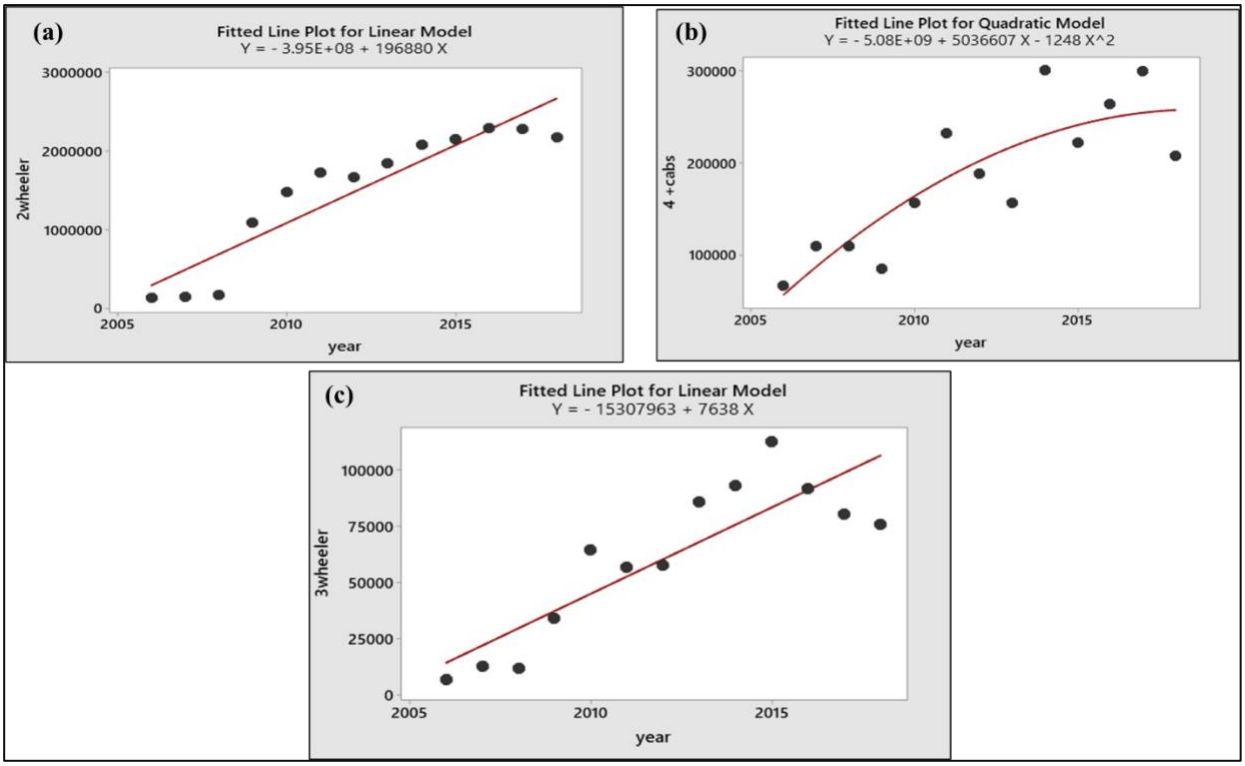

Figure II. Regression model for estimation of Vehicles Sale by 2030 (a) 2 wheelers (b) 4 wheelers (c) 3 wheelers.

2 Wheelers	$S = -3.95 \times 10^8 + 196880(year)$	Eq. 4
3 Wheelers	$S = -15307963 + 7638(year)$	Eq. 5
4 Wheelers	$S = -5.08 \times 10^9 + 5036607(year) - 1248(year)^2$	Eq. 6

Table V. EV prediction model

Considering medium-term targets as Scenario 1 and long-term targets as scenario 2, the number of EVs are estimated for from Equations 4, 5, and 6, which are obtained from the regression model applied on the data gathered for vehicle sales over the past 15 years and the results have been presented in Figure 3. From where, it is clear that for medium targets, around 4.3 million cumulative 2 and 3 wheelers EVs will be required, while to meet the long term targets the required combined 2 and 3 EVs should 11.6 million by 2030. To meet the targets, the 4 wheelers EVs should be around 300,000 for medium targets while for long term targets, these should be around 715,000 by 2030. These numbers show that there would be a good quantity of EVs that will be present in 2030 and to run these EVs the significant amount of electrical energy would be required. The electricity required to run the EVs have been estimated using Equation 1 and the results have been presented in Figure 4. For Scenario 1, around 6.5 GWh electrical energy is required on daily basis to run the EVs out of which 2.1 GWh/day will be required by 2 and 3 wheelers while 4.4 GWh/day will be required by 4 wheelers. For long-term targets, termed as Scenario 2, more electrical energy will be required because of high number of EVs. Around 16.28 GWh/day electrical energy will be required to meet the long-term targets. Out of which, 5.633 GWh/day will be required by 2 and 3 wheelers while the rest of energy will be required by the 4 wheelers.

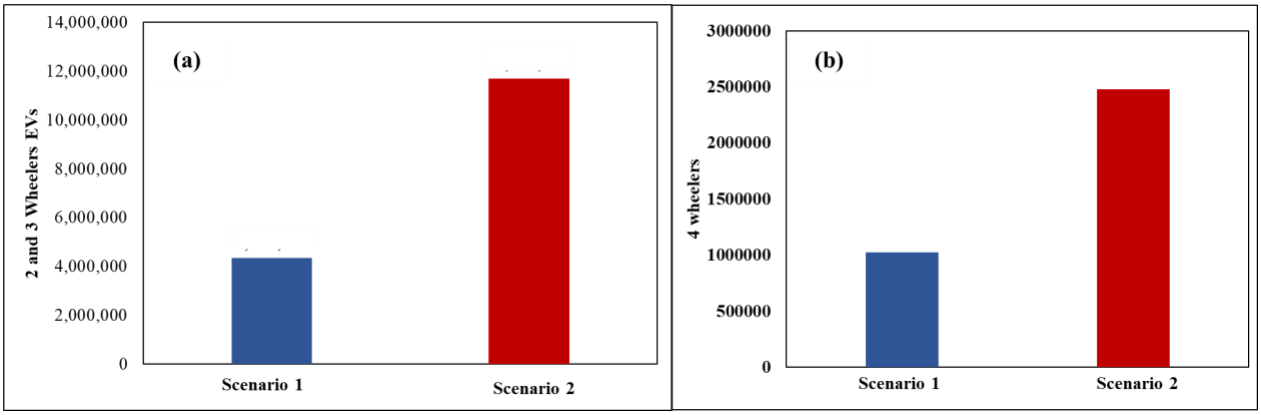

Figure III. EVs prediction (a) 2 and 3 wheelers (b) 4 wheelers.

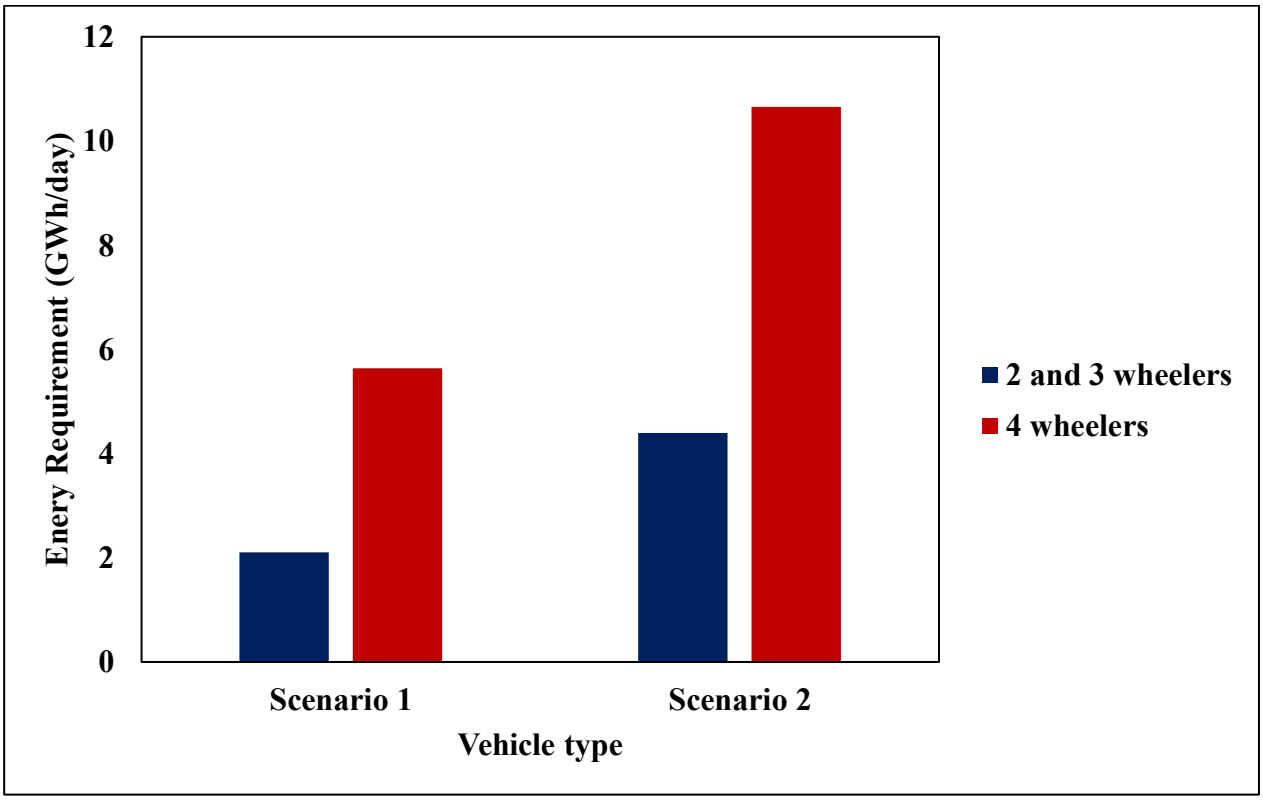

Figure IV. Electrical Energy Requirement by different EVs.

The charging infrastructure requirement for major cities of Pakistan has been estimated by using Equation 2 and the results are presented in Table 6. The charging infrastructure requirement has been estimated by considering the policy requirement which restricts one DC fast charging station in every 3 by 3 km range in all the major cities like Karachi, Islamabad, Lahore, etc. These charging stations must be enough to support the electrical energy requirement by EVs. The area of Karachi is 3780 km. sq. so for 1 DC charging station in every 3 by 3 km, there will be a need for 420 charging stations only in Karachi. Similarly for other major cities like Lahore, Islamabad, Faisalabad, Peshawar, Rawalpindi, Gujranwala, Hyderabad, and Quetta, the number of charging stations would be 197,100, 144, 23, 29, 27, 32, and 19 respectively. Since the policy aims at building charging infrastructure in the major cities that is why smaller cities are not considered, the number of charging stations to be installed in these cities by 2030 sums up to be 991.

City	Number of Stations
Lahore	197
Islamabad	100
Faisalabad	144
Peshawar	23
Rawalpindi	29
Gujranwala	27
Quetta	19
Hyderabad	32
Karachi	420
Total	991

Table VI. Charging Stations required in Major Cities.

The economic assessment of electric vehicles (EVs) begins with quantifying the cost benefits that stem from their use, which can be computed as the difference between EV utilization expenses and FFV utilization costs. In Pakistan, the transport industry uses oil the most, as it makes up 34% of energy consumption and 59% of liquid fuels. Financial savings due to lesser oil consumption were calculated using Scenario 1 and Scenario 2 data, assumptions and average oil import price as shown in Equation 3. The results are presented in Tables 7 and 8. In Scenario 1, the total cost savings is estimated at $812 million, while Scenario 2 estimates the cost savings at $2,149 million. All cost figures are in USD. This showcases the remarkable economic impact that EV integration offers for the transport sector. If adapted, Pakistan would reduce the burden its imported oil has on the economy, curb trade imbalance, and improve energy independence. It also contributes to sustainable development through advancing cleaner transportation options. Both scenarios greatly showcase the savings that would be seen in costs, which demonstrates the positive economic outlook that EV integration brings.

Scenario 1					
YEAR	TOTAL VEHICLES	EVs	FFV	% OF FFV	COST SAVED (Mil. $)
2021	32,777,068	75,903	32,701,165	99.77%	6.279856805
2022	37,608,978	235,053	37,373,925	99.38%	16.94872923
2023	42,633,853	482,984	42,150,869	98.87%	30.72137116
2024	47,849,197	830,284	47,018,913	98.26%	47.05592934
2025	53,252,514	1,282,301	51,970,213	97.59%	65.29985323
2026	58,841,308	1,846,006	56,995,302	96.86%	85.0772001
2027	64,613,083	2,528,277	62,084,806	96.09%	106.1125401
2028	70,565,343	3,335,901	67,229,442	95.27%	128.1988555
2029	76,695,592	4,275,569	72,420,023	94.43%	151.1770904
2030	83,001,334	5,353,881	77,647,453	93.55%	174.9226881
				TOTAL	**811.7941139**

Table VII. Cost saving for Scenario 1.

Scenario 2					
YEAR	TOTAL VEHICALS	EV SCENARIO 2	FFV	% OF FFV	COST SAVED (Mil. $)
2021	32,777,068	199,664	32,577,404	99.39%	16.51935157
2022	37,608,978	618,902	36,990,076	98.35%	44.62652185
2023	42,633,853	1,277,397	41,356,456	97.00%	81.25195391
2024	47,849,197	2,194,608	45,654,589	95.41%	124.3783385
2025	53,252,514	3,389,769	49,862,745	93.63%	172.6205406
2026	58,841,308	4,881,891	53,959,417	91.70%	224.9925793
2027	64,613,083	6,689,758	57,923,325	89.65%	280.7710869

2028	70,565,343	8,831,931	61,733,412	87.48%	339.4115783
2029	76,695,592	11,326,745	65,368,847	85.23%	400.4950923
2030	83,001,334	14,192,313	68,809,021	82.90%	463.693047
				TOTAL	**2148.76009**

Table VIII. Cost saving for Scenario 2.

4. Conclusion. - The predictions and calculations done in this paper indicate that the introduction of EVs in Pakistan's transport sector will be beneficial for lowering carbon emissions by replacing conventional cars. The introduction of EVs will also be encouraging private and government sectors to invest in clean and renewable energy, however, the clean energy generation in Pakistan is already gradually growing as discussed above moreover it will promote the idea of clean and renewable energy among normal individuals. Talking about power, these electric vehicles will need 6.5 GWh/day and 16.28 GWh/day according to Scenario 1 and 2 respectively. Other than the environmental benefits of EVs in Pakistan there is also a huge economic benefit too, Pakistan being a net importer of oil is a huge burden on Pakistan's economy currently Pakistan imported 41,196,704 barrels of oil in the year 2020-21 from which almost 34% will be for the transport sector, this indicates that replacing conventional vehicles with EVs will directly affect Pakistan's economy. According to the calculations done in this paper, the total cost saved over the period of 10 years from scenario 1 is estimated to be 812 million dollars and can reach 2149 million dollars if we consider scenario 2. All this discussion leads to the result that EVs are the best option for Pakistan to deal with Environmental issues and with the burden of oil import in the country. A renewed EV policy by the government of Pakistan is much needed to accelerate EV growth by further decreasing import duties on EVs and related technology to increase public awareness by providing incentives to the buyers, moreover invest in building up infrastructure and charging stations across the motorways and highways of Pakistan.

5. Declaration. - The authors would like to declare that there is no conflict of interest. Authors would also like to declare the use of Artificial Intelligence in improving the overall text of the manuscript.

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2. Data acquisition
3. Data analysis
4. Discussion of the results
5. Writing of the manuscript
6. Approval of the last version of the manuscript

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