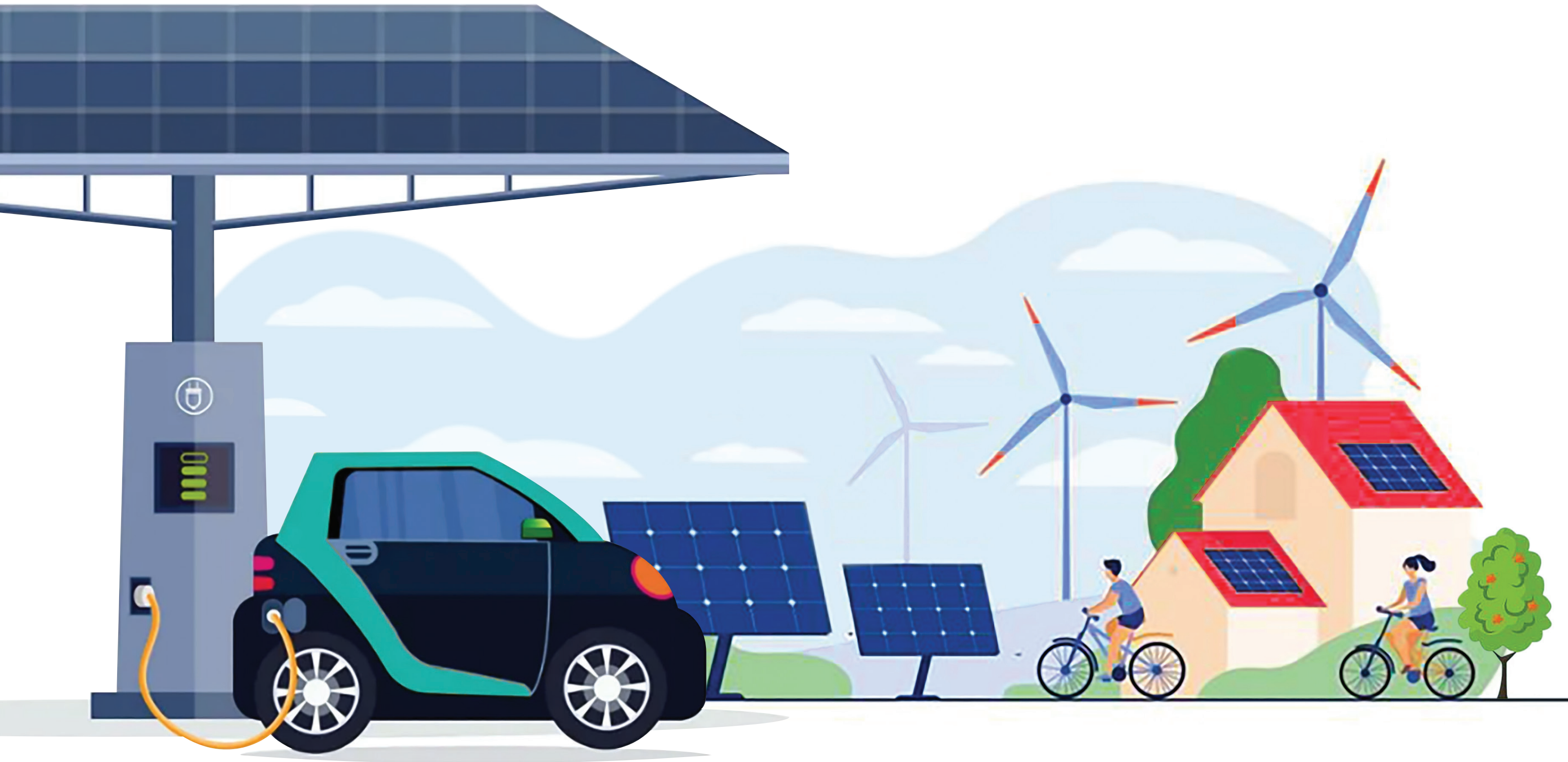
Scaling Up Electric Mobility in Pakistan



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Executive Summary

Globally the electric vehicles (EV) are gaining substantial momentum due to their higher energy efficiency, lower running and operations costs, as well as lower tailpipe emissions. As a result of these multiple benefits, the global electric vehicle fleet has been expanding at a rapid pace - primarily driven by policy support by leading governments, technology improvements and declining battery costs.

The road transport sector in Pakistan relies heavily on fuel imports. Pollution in major cities has increased to alarming levels. Apparently, Pakistan currently faces a power surplus crisis. Increased EVs penetration could serve as a productive power demand and help achieve an adequate level of utilization of existing power capacity and bring down unit cost of electricity. Electrification of transportation is one of the effective means to reduce energy intensity in the road transport sector. Besides, EVs offer lower running and operational costs, and as well as lower tailpipe emissions. All these factors put together make a strong case for EV adoption in Pakistan.

While recognizing the multiple economic, environmental and social benefits of electric mobility, Government of Pakistan introduced its first ever National Electric Vehicle Policy (NEVP) for various vehicular segments in 2020.

Globally, EV growth has mainly been driven by four factors; purchase cost of an EV, driving range, diversity of EV variants and reliable access to charging infrastructure. Over the recent years, the economics of this technology has massively improved. This report provides an insight into global EV market, highlights key drivers for global EV adoption, reviews national EV policy of Pakistan in comparison to other leading economies and underlines the global EV battery value chain.

Subsequently, the report examines the EV charging technology and infrastructure based on international standards and best practices. In the end, it provides some recommendations on policy measures, incentives, interventions for the type of infrastructure needed for Pakistan and standardization of EV charging stations.

This work undertakes a comparative assessment of Pakistan's national EV policy and emerging EV markets in the US, EU, China, and India in the context of EV deployment targets, carbon emission regulations, fuel economy standards, phase-out plans for Internal Combustion Engine (ICE) vehicles and purchase incentives for EVs.

Further policy push and support is required to accelerate the EV adoption

The rate of EV penetration in Pakistan is not easy and straightforward to contemplate. However, there are four critical factors that will influence the EV adoption in the country over the next decade – policy support, global battery costs, charging infrastructure and localization of supply chain.

Promulgation of NEVP has set the ground for promotion of electric mobility in Pakistan and with further policy and regulatory support, this intervention could help accelerate this transition to achieve following three major goals;

I. Reduce fuel imports and thus, improve Pakistan's energy security;
II. Reduce energy intensity of road transport by leveraging higher efficiency of EVs over conventional vehicles; and
III. Reduce carbon footprint and vehicular emissions of particulate matter to improve urban environment.

National EV policy has set EV market penetration targets and calls for achieving 30% of new sales of all passenger vehicles and 50% of two, three wheel and buses by 2030. NEVP outlines various incentives in the form of duty concessions for import of EVs, associated parts and chargers; duty-free import of plant and machinery for EVs for local assembling, and other benefits, including exemption of EVs from registration fee, annual renewal and sales tax etc.

While the government has provided some decent concessions on duties and taxes on local manufacturing of EVs but policy does not offer any purchase incentive for EVs. At present, purchase cost of an EV is significantly higher than ICE vehicles. To reduce this price gap, many countries around the world have provided generous subsidies to incentivize EV purchase.

It is critical to recognize at an early stage; it may be justifiable to incentivize import of essential parts and assembled units of EVs for scaling up the adoption till the market is developed for local manufacturing. Policy makers may need to realize that further thrust may be required in the form of more relaxed duties and taxes for EV adoption.

Consultative meetings with stakeholders revealed that private sector is keen on exploring this emerging electric mobility space, however, clear policy direction from the government seems to be somewhat lagging. EV market in Pakistan is quite nascent and at a very early stages of its development. Despite the big hype for electric cars, we do not see enough momentum for passenger electric cars in the market. At the moment, there are only a handful of Original Equipment Manufacturers (OEMs) active in this space and largely the market focus has been on the Two Wheelers (2W) and Three-Wheeler (3W) segments.

The Total Cost of Ownership – EVs vs ICE

This report assesses the economic viability of EVs across different vehicle segments and various use cases today using the Total Cost of Ownership (TCO) analysis. TCO is the sum of all costs involved in the purchase, operation and maintenance of a given asset during its lifetime. TCO analysis can be helpful in assessing as to how the EV market is positioned in terms of potential sales based on TCO, who are the current leading market players and, most importantly, how is the market expected to change in the future based on inflection points across various use cases.

TCO analysis indicates that electric 2W and 3W are already at TCO parity with ICE equivalent for both personal and commercial use. While electric cars are economically viable for commercial fleet operations with high daily utilization and, TCO parity for personal use is not attractive yet. Whereas, buses have a very high upfront cost differential (>100%) due to the large size of the battery. We believe that TCO parity can be achieved at the daily usage of over 250 km.

Charging Infrastructure is the key to scale up EV adoption

The report underscores that widespread, accessible public charging infrastructure network is needed to support a robust EV market. Worldwide, the charging infrastructure presents a "Chicken and Egg" dilemma. On one hand, the investors are reluctant to invest in this new market, and on the other hand, consumers are uncertain to adopt EVs without widespread and reliable charging infrastructure. Hence, success of this transition depends on how quickly the adequate charging infrastructure can be put in place to drive the EV adoption.

Seemingly, with low market EV penetration, it is expected that the utilization of charging stations would continue to remain low at initial stage. In this case, it would be challenging for private sector to make an investment into charging infrastructure. Hence, some kind of infrastructural support from the government may be needed with targeted subsidies towards installation of charging infrastructure. This will not only address the range anxiety issues amongst current EV owners but it will also serve as demonstration effect for general public, which can further improve consumer confidence in this emerging market. While EV policy has provided some incentives for charging equipment with reduced duties and taxes, it requires further regulatory and financial support to help accelerate this transition.

The review of global EV charging infrastructure demonstrates that it plays a predominant role in uptake of EV adoption. Current charging technology offers a range of solutions for various vehicular segments and the type of charging technology deployment depend on type of vehicle, commuting pattern, and charging behaviors. Considering many dynamic variables of electric mobility, it is quite a challenge to ascertain the EV penetration and the corresponding need for charging infrastructure.

Current EV charging ecosystems has some interoperability challenges due to regional differences and choice of automakers. Therefore, standardization of EV charging stations would be critical for Pakistan, as it would provide clarity to manufacturers, ensures compliance with safety standards, allow EV owners to charge their vehicles at any charging point with an ease of access and allows for economies of scale for manufacturers. To overcome of these interoperability challenges, this report provides recommendations on adoption of relevant standards for installation, operations and safety of EV charging equipment and stations.

This work assessed the climate benefits of projected increased in EVs on Greenhouse Gases (GHG) emissions. To investigate the potential impact of electric mobility in Pakistan, an excel based model was developed to assess economic, energy and climate benefits of EVs. Broadly, the model computes EV market penetration under three distinct scenarios; and based on these cases - we determine EV induced fuel saving potential, impact on import expenditure, electricity demand and net impact of GHG emission mitigation potential.

Key Takeaways

- **EV Penetration:** In a best-case scenario that assumes high EV penetration targets; cumulative EV population is linearly projected to increase from 25,000 units in 2021 to 8.2 million EVs in 2030 during the period 2021-2030. While in a medium (consistent with NEVP) and low EV market growth case, cumulative EV population is projected to be 4.8 million units and 2.2 million, respectively during the same period.

- **Impact on Fuel Demand (Petrol and Diesel):** EVs were found to reduce energy consumption and emissions compared with similar ICE vehicles, based on modeled scenarios. With the best-case scenario, high EV penetration in the market would offer a fuel reduction of over 18 Million Tonnes of Oil Equivalent (MTOE) during the period 2021-2030. Similarly, in a medium EV penetration case, potential reduction in fuel consumption is computed to be about 10 MTOE and, in the low growth scenario, it is estimated to be about 5 MTOE.
- **Impact on Electricity Demand:** Even in the high EV penetration case with cumulative addition of over 8.2 million EVs by 2030, our model demonstrated that high EV penetration is not likely to cause large increases in power demand through 2030; instead, it potentially adds about 2 percent to the total and requires about extra 1.7-2 gigawatts (GW) of generation capacity by 2030.
- Hence, high market EV deployment is not likely to be a major challenge for electricity grid network in Pakistan. However, EVs would likely reshape the electricity demand curve and might coincide with existing peak loads in the evening if majority of EV owners decide to charge at home after work. Hence, we propose Time of Use electricity tariff to influence charging behaviors and incentivize charging at off-peak periods to manage peak demand.
- In addition, we could see power spikes in some areas with high saturation of charging station in certain locations with limited grid capabilities. To address this challenge, distribution companies would need to foresee anticipated demand for EVs and invest into network expansion and strengthening to facilitate high uptake of EV charging infrastructure.
- Placement of high-capacity fast chargers (Level 3 - 50 kW and above) everywhere would exert significant strain on the distribution network. This would be especially problematic during summertime, when the power network is already overloaded during that period. Therefore, Level 3 should only be prioritized at specific locations where they are needed the most at highways and motorways.
- Worldwide, Level 2 (7-22 kW) chargers are prevalent, and we propose the policy makers and grid infrastructure planners must encourage Level 2 chargers for most urban locations, such as in the offices, commercial spaces, malls, hotels and universities etc. By doing so, we would be able to address and manage the potential strain on the grid and provide cheaper electricity rates for charging, as Level 2 has much lower infrastructural and capital cost than the Level 3 chargers.

- **GHG Emission Mitigation Potential of EVs:** The GHG emission mitigation potential of EVs is measured in the form of reduced demand for fuels with increasing share of EVs. Results show that EVs offer tremendous climate benefits in terms of net emission reduction even after factoring in the grid emissions. This analysis highlights that climate benefits of electric mobility in Pakistan would continue to increase with further decarbonization of the grid to meet the target of 30% of renewables in total electricity generation as planned under the Alternative and Renewable Energy Policy 2019. We found that EV could achieve climate benefits within the range of 10 MTCO2-eq to 40 MTCO2-eq GHG emission reduction per year by 2030.

The scope of this work was extended to determine the financial viability of commercial EV charging facilities in Pakistan. This analysis is primarily meant to assist National Electric Power Regulatory Authority (NEPRA) in its determination of electricity tariff for EV charging station and decide on adequate profit margin for the station operators or owners. Commercial EV charging should be profitable so that it is sustainable. At the same time, commercial EV charging should offer economic value to an EV owner, and it should be considerably cheaper than equivalent fuel cost of an Internal Combustion Engine (ICE). To evaluate profitability of EV charging stations, a Net Present Value (NPV) and Internal Rate of Return (IRR) analysis is conducted using a discounted cash flow (DCF) model.

Key findings on Economics of Charging Stations:

- The analysis has demonstrated that utilization of a charging station is the single most important variable with the greatest impact on financial viability of charging station. Once an EV-charging station is built, all costs are essentially fixed, so utilization is key to achieving financial efficiency.
- We considered the maximum cost of charging an EV at a public charging station below which consumers would be willing to pay at a commercial charging station. We factor in this "willingness to pay" as a price range between a fuel cost for an ICE vehicle and residential charging at the off-peak hours, which is the cheapest option available to an EV owner. So, charging should always be cheaper than fuel equivalent cost of an ICE vehicle.
- The results demonstrated that the Level 4 - 150 kW perform better on breakeven price (a point when NPV becomes zero or positive) than Level 3 for lower levels of utilization. It is due to the fact that 150 kW injects more electricity than 50 KW charger in a given level of utilization and hence, it is able to produce higher sales which offsets the higher capital costs.
- The analysis suggests that for higher levels of power, a given level of utilization produces more additional revenue than additional cost, hence lowering the average margin the operator must make to break even. At progressively higher levels of utilization, there is a sharp decrease of breakeven price.
- The results suggest that with utilization at 10%, commercial chargers are almost not economically profitable, suggesting a significant, sustained increase in demand that will be needed for commercial charging infrastructure to deliver financial returns, and compete with both ICEs and cheaper residential charging.
- The analysis has demonstrated that for levels of utilization at 20% and above, Level 3 and Level 4 DC Fast Charging breakeven electricity prices can be competitive with petrol prices. But only at 40% utilization, Levels 2 and 4 become competitive with an efficient hybrid vehicle and residential charging at peak hours. Our model also demonstrated that not any level of commercial charging is competitive with residential charging under off-peak rates.
- For DC fast chargers, demand charges can dominate operating costs. Demand charges reflect the projected cost to the utility of providing the generation and distribution infrastructure required to meet peak demand on both a system level and a local distributional level. As a result, the total cost of power from fast charging stations is higher than slower residential chargers. In the early stages, we recommend that demand charges should be kept at the minimum level or may waived off altogether to encourage investments into the charging infrastructure and to reduce the final price to the end consumers.

Key Policy Recommendations:

- ***Ensure policy implementation through robust regulatory framework to support electric vehicle deployment.*** While top-level policy is in place, reflecting high-level aspirations, however, there has been a limited action from relevant agencies in setting out clear directives for taxation, import clearance, instructions and procedures for implementation of this national EV policy. The absence of operational-level work is a fundamental barrier to EV market development. For effective policy implementation, key entities need to develop and notify relevant regulations and procedures.

- ***Promotion of strategy for 'Make in Pakistan'*** Transition to electric mobility for Pakistan would not be sustainable unless we make efforts to promote strategy for 'Make in Pakistan'. This requires development of indigenous market and channelize investments into local manufacturing of critical parts, including batteries, motors and electronics for EVs. The most critical part in this entire value chain is lithium-ion battery. Pakistan would have to make strategic partnership to secure supply of key raw materials like Lithium, Cobalt, Nickel for local production to meet the increasing demand by 2030. China dominates the battery production industry, and we can leverage our partnership with China for local manufacturing of lithium-ion cells in the country.
- ***Regulatory framework for Charging Infrastructure is critical*** to streamline the development of uniform EV charging stations across the country. Relevant entities, including, NEECA, NEPRA, DISCOs, and PSQCA shall define clear permitting, licensing and approval procedures for setting up an EV charging stations. National Energy Efficiency and Conservation Authority (NEECA) is well positioned to be designated for facilitating one window operation for setting up, permitting, ensuring, compliance and oversight towards development, standardization of EV charging infrastructure in the country. This would be an essential step to develop the set of technical standards and safety precautions that govern the EV chargers to promote and facilitate the sustainable uptake of EV charging infrastructure.
- ***Establish national fuel economy and emission standards*** Despite the fact that road transport sector heavily relies on oil imports, Pakistan has not yet established the national fuel economy standards for local automotive manufactures. It is extremely critical for Pakistan to establish its national fuel economy standards for auto manufactures with a vision to reduce energy intensity of road transport sector, depress oil imports, increase energy security and help protect the environment. In this context, the role of NEECA and Engineering Development Board (EDB) remain critical for the sustainable transition towards clean and efficient mobility in the country.
- ***Charging Infrastructure plays a key role in enabling and supporting EV adoption.*** DISCOs need to plan ahead for system upgradation to mitigate the grid impacts – transformers, distribution lines and switch gears. NEPRA may introduce and employ Time of Use pricing models (off-peak and peak electricity rate) to manage the impact of increasing demand on local distribution network. Standardization of charging infrastructure is the key to help develop safe, reliable, accessible and affordable EV charging ecosystem.
- ***Develop adequate financing, technical and human resources capacity to scale up the uptake of EVs*** Currently, there is insufficient expertise on the job market, and inadequate technical support to electric vehicle operators and consumers. This necessitates additional training and skill development for practicing mechanics and technicians in workshops and garages to handle EV related maintenance and operations. Hence, it is essential to introduce capacity building programs with donors' support for both private and public sector professionals, technicians and engineers.

Chapter – I: Global Electric Mobility Market

Globally the electric vehicles (EV) are gaining substantial momentum due to their higher energy efficiency, lower running and operations costs, as well as lower tailpipe emissions. As a result of these multiple benefits, the global electric vehicle fleet has been expanding at a rapid pace - primarily driven by policy support by leading governments, technology improvements and declining battery costs.

According to the Global EV Outlook 2020, the sales of electric cars reached 2.1 million in 2019 – pushing up the global stock of over 7 million EVs. Exhibit 1 presents worldwide sales of EVs wherein China dominates the world's EV market, with 2.3 million electric vehicles in active use. Whereas, for many countries in the EU, the EV market is amped up and quickly rising. However, in many countries the transition to electric mobility is still at an early phase, including Pakistan. While recognizing the multiple economic, environmental and social benefits of electric mobility, Government of Pakistan introduced its first ever National Electric Vehicle Policy (NEVP) in 2020.

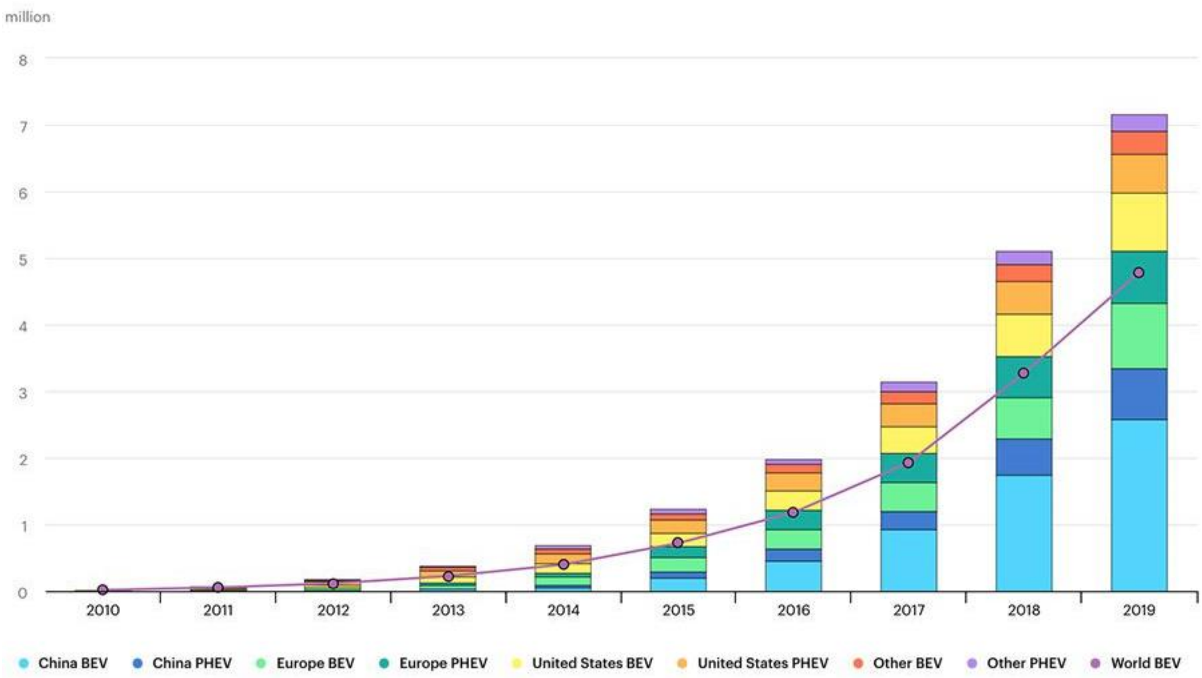


Exhibit 1: Global Electric Vehicle Sales, 2010-2019, Source: International Energy Agency (IEA)

EVs will reduce the national fuel import bill, bring down emissions and create a new market for automakers, thereby creating employment and promoting clean mobility in Pakistan. This chapter mainly provides an insight into global EV market, national EV Policy of Pakistan alongside a comparative assessment with other leading economies, and in the end, it highlights the global Lithium-ion battery industry.

This section begins by establishing a policy evaluation rubric to review the Pakistan's national EV policy in comparison to emerging EV market leaders; US, EU, China, and India especially in the context of EV deployment targets, carbon emission regulations, fuel economy standards, phase-out plans and purchase subsidies.

As the name suggests, an Electric Vehicle is powered by an electric motor(s) that draws current from a rechargeable battery and consumes electric current as a fuel. In this paper, the term EV mainly refers to Plug-in-Electric Vehicle (PEV), which is a pure electric vehicle that operates solely on the electricity stored in a battery that can be recharged from the grid or any distributed generation source. Depending on battery capacity, EVs offer a range of 100 to 400 km.

Global EV Market

Global electric vehicles crossed 7 million units in 2019 with annual sales crossing 2.2 million units. Currently, China is way ahead in the EV adoption race with almost half of the global electric car sold in the country in 2019[1]. Europe and the USA are the next leading markets with 26% and 14% share, respectively, while Norway, Iceland and Netherlands continue to dominate the European markets in terms of EV penetration.

Globally, EV growth has mainly been driven by four factors; purchase cost of an EV, driving range, diversity of EV models and the charging infrastructure. Price comparability is one of the most significant barriers, since EVs still cost more compared similar combustion engine vehicles. Many countries have addressed this issue of higher cost differential by offering generous subsidies. As the prices of EVs drop further, the global market would continue to see more electric vehicles on the roads.

The second most important factor is the driving range and it is often associated with "range anxiety". It is the fear that an EV may have an insufficient range to reach its destination. Thus, building public EV charging infrastructure is essential for EV adoption to take place and overcome the range anxiety. Moreover, many car manufactures are investing heavily on battery technology development to allow for more distance travel on a single charge.

China

China has outpaced the world in EV adoption by a huge margin with almost 50% of the global electric car market. China has achieved this massive market growth in large part due to its generous subsidy program. There is an estimate that over US$ 60 billion has been pumped into the electric vehicle's ecosystem over the last decade[2].

China originally launched its subsidy program in 2009. Initially, each electric car was offered with a purchase subsidy of US$ 8,000. Recently, as the EV market has picked up momentum, China is gradually cutting down these subsidies. Now the maximum subsidy is caped at US$ 3200 for each vehicle with driving range of over 400 km.

In 2019, China introduced an electric car quota policy under its New Energy Vehicles (NEVs) program pushing automakers to generate EV credit points[3]. Car manufacturers can be penalized if they do not

[1] Global EV Outlook 2020, International Energy Agency (IEA)
[2] EQ International 2019 https://www.eqmagpro.com/beijing-gave-its-biggest-electric-vehicle-maker-1-billion-in-help-toward-a-single-year-of-sales/
[3] China powers up electric car market, BBC 2019 https://www.bbc.com/news/business-46745472

meet required the credit points as per the quota. Secondly, it will be hard for them to build new manufacturing plants for combustion engines.

In addition, car manufacturers are also required to meet the average fuel economy standard of 5 liters per 100 km. Meeting these two policy instruments together obligate the automakers to achieve significant adoption towards EVs.

Besides, China has also built a massive charging infrastructure. Today, China has 515,908 publicly accessible charging points i.e., 60% of the world, followed by the USA which has 77,358 points and the Netherlands with 50,153 points.

The European Union (EU)

In the EU, sales of electric vehicles have been growing significantly in recent years, largely driven by favorable policies, financial incentives and CO_2 regulations. Some of the European member countries have achieved the highest penetration of electric cars. For instance, Norway has a market share of 56% in 2019, followed by Iceland (25%) and the Netherlands records the third-highest market share of 14%.

U.S.A

Initially, the USA was among the earliest adopters of EVs. However, the EV market could not pick up significant growth in comparison to the Europe and China in terms of annual sales. In 2019, a total of 326,000 electric vehicles were sold in the USA vs over a million vehicles in China.

The lower sales in the USA could be attributed to lower fuel costs amongst advanced economies and perhaps differences in the passenger car market, which has a relatively higher proportion of sport utility vehicles (SUVs). Options are limited for EVs in SUV segments.

The EV penetration in the USA varies significantly across the states and it corresponds to a diverse range of incentives offered by states. For example, California is the largest EV market in the USA. Apart from providing the highest incentives which range from US$ 2,500 to US$ 7,000, also offers several other benefits, such as access to the dedicated lanes in selected areas and discounts on recharging. The USA also offers tax credit up to US$ 7,500 under its federal program on the purchase of an EV.

India

India adopted its National Electric Mobility Mission Plan (NEMMP) in 2013 with an ambition to add 6-7 million EVs on the road by 2020[4]. The major thrust behind this initiative was to achieve fuel savings to the tune of 2.5 million tones[5]. However, the total sales of EVs remained under 3000 in 2019, which is quite insignificant for a large economy like India.

[4] Ministry of Heavy Industries and Public Enterprises, Government of India

[5] National Electric Mobility Mission Plan 2020 https://policy.asiapacificenergy.org/node/2663

In 2015, the government introduced Faster Adoption and Manufacturing of Electric Vehicles FAME-I initiative as part of NEMMP. A total of 300,000 vehicles were supported with subsidy as part of FAME-I program.

Subsequently, government introduced FAME-II scheme in 2019 to promote EV adoption through direct subsidies. This program offers subsidy at US$ 130/kWh for all vehicles except buses and trucks. FAME-II also aims to provide subsidy to set up over 2700 public charging infrastructure.

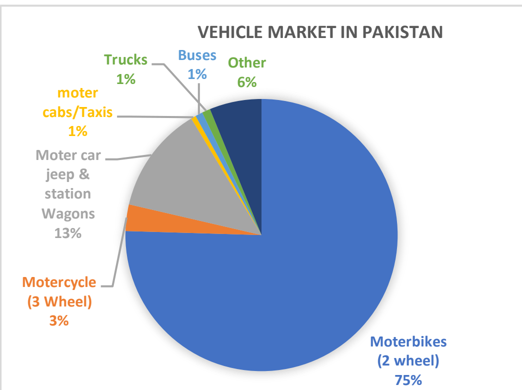
National Electric Vehicle Policy of Pakistan

The rate of EV penetration in Pakistan is not easy and straightforward to contemplate. However, there are four critical factors that will influence the EV adoption in the country over the next decade – these include, policy support, global battery costs, charging infrastructure and localization of supply chain.

Promulgation of NEVP has set the ground for promotion of electric mobility in Pakistan and with further policy and regulatory support, this intervention could help accelerate this transition to achieve following three major goals;

IV. Reduce fuel imports and thus, improve Pakistan's energy security;
V. Reduce energy intensity of road transport by leveraging higher efficiency of EVs over conventional vehicles; and
VI. Reduce carbon footprint and vehicular emissions of particulate matter to improve urban environment.

The road transport sector in Pakistan has been growing at a significant pace. The total number of registered vehicles stood at 29 million in 2019[6]. Two-wheelers or motorbikes hold dominant share which represents over 75% of the total vehicles with an average sale exceeding over 2 million annually. Over the period of nine years, two- and three-wheel vehicles have recorded a very high annual growth rate at 17%.



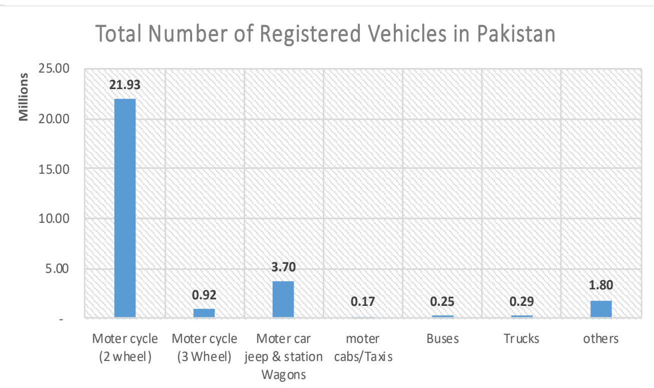


Exhibit 2: Automotive Market in Pakistan[7]

Motorbikes or two-wheelers are an important consideration in the EV policy, because they consume about 50% of the total petrol usage in the country. Consequently, higher sales of motorbikes have corresponded with higher consumption of petrol with 23%[8] year-on-year rise. If this trend continues,

[6] Economic Survey of Pakistan 2019-20, Statistical Appendix – Transport and Communication.
[7] Economic Survey of Pakistan 2019-20, (Statistical Appendix)
[8] Energy Year Book, 2020

the import bill of petrol could potentially shoot up to unsustainable levels. This is in contrast to the passenger sedan cars and SUVs having grown an average of 8% per year, and buses and trucks have recorded an average annual growth at 3%, during the same period.

Table 1 provides the EV penetration targets for the medium and long term as underlined in the policy document by the Ministry of Climate Change (MoCC). Over the next five years, the government has set the goal of adding an electric fleet of over 100,000 sedan cars and 500,000 two- and three-wheel vehicles. While in the long-term for 2030, the policy aims to electrify 30% of all the passenger vehicles and add heavy-duty electric trucks by 2030, and 90% by 2040. The policy underlines even more ambitious targets for two- and three-wheelers and buses, i.e. 50% of new sales by 2030 and 90% by 2040.

EV Penetration Targets	Medium Term Targets (Five Years) Cumulative	Long Term Targets (2030)	Ultimate Targets (2040)
Cars (including Vans, Jeeps and small Trucks)	100,000	30% of New Sales (Approximately 60,000)	90% of New Sales
Two and Three Wheelers Four Wheelers of UNECE 'L' Category	500,000	50% of New Sales (Approximately 900,000)	90% of New Sales
Buses	1,000	50% of New Sales	90% of New Sales
Trucks	1,000	30% of New Sales	90% of New Sales

Table 1: Electric Vehicle Penetration Targets[9]

Worldwide, major barriers to mass adoption of EVs are typically higher purchase costs, limited driving range of EVs, and lack of charging infrastructure. Higher purchase costs act as major impediment to EV adoption, especially in the case of underdeveloped economies. Thus, policy instruments can play predominant role in scaling up the uptake of electric vehicles.

Governments around the world have introduced ambitious policies with wide array of subsidies, purchase incentives for EVs and investments in public charging infrastructure to support the transition towards electric mobility. Leading nations in this space demonstrate that policy incentives are extremely critical to help drive momentum for mass EV adoption. These incentives provide a strong signal both to manufacturers and consumers, which is essential to build the confidence at the early stage of market development. This holds true for Pakistan as well. Without robust policy support and financial incentives, growth in the EV market cannot be sustained.

The policy support can be in form of long-term regulatory signals with targets for EV with specific timeframes, CO2 emissions regulations, fuel economy standards, the phase-out of internal combustion engine vehicles and financial support. In order to assess the effectiveness of Pakistan's EV policy, a rubric evaluation is undertaken which assesses key metrics and interventions through a comparative analysis with other leading and emerging economies as provided in the Table 2 below.

EV targets with timeframes for introducing the electric vehicles is a good starting point and it serves as a fundamental policy signal for market development. Like many other countries, Pakistan's EV

[9] National Electric Vehicle Policy 2019, Ministry of Climate Change (MoCC)

policy has also set this target of achieving 30% of new sales by 2030. In addition, many countries around the world have placed emissions and fuel economy standards. In certain cases, Original Equipment Manufacturers (OEMs) or automakers can be penalized if they do not meet those benchmarks. These standards in some way help drive EV adoption by potentially pushing car manufacturers to add EVs in their existing assembly or manufacturing lines.

Variables	Zero Emission Vehicle (ZEV) Targets	Average vehicle fleet emission target (gCO2/KM)	Fuel Economy Standards (Liters/100KM)	Phase-out of Internal Combustion Engine Vehicle	EV Purchase Incentives
China	30% of New Sales of EV by 2030	117 gCO2/km for 2020	4.0 L/100km by 2025	-	US$ 3,200 with maximum price of EV at US$ 42,400
USA	3.3 million EVs by 2025	93 gCO2/KM by 2025	4.25 L/100KM by 2025 for passenger cars, and 5.985 L/100km for light duty trucks by 2025	2050	Tax credit up to US$ 7500
India	30% of New Sales of EV by 2030	113 gCO2/km for 2021	4.77 L/100km for sedan cars by 2022	Earlier adopted this target for 2030 but later withdrew	US$ 130/kWh - US$ 400 for 2/3 wheels and US$ 2000 for 4 wheels
Europe	30 million zero-emission vehicles on its roads by 2030	95 gCO2/km for 2020	4.1 L/100 km by 2021	Netherland, Iceland, Ireland and Denmark by 2030, France and Spain by 2040, Germany by 2050	US$ 2000-7000 depending on the type of the vehicle and capacity of the battery
Pakistan	30% of New Sales of EV by 2030	-	-	-	-

Table 2: Incentives/Regulatory Signals and policy driven support for Plug-in-Electric Vehicles
Source: Authors' compilation

Pakistan has adopted an emission regulation in the form of Euro standard. However, there is not any directive on carbon dioxide emission so far in the country. Similarly, the country has not yet adopted any national fuel economy standard. It is important to note that in the absence of these benchmarks, there is no motivation for automakers to introduce more efficient variants in the markets. Besides, these benchmarks are quite significant in monitoring the progress towards the commitment that Pakistan has made under the Paris climate agreement.

Besides, leading economies have announced long-term commitments to phase out internal combustion engine vehicle to achieve 100% EV. For example, countries in Europe like Norway, the UK, France, and Germany have set the timelines to ban combustion engine vehicles. Interestingly, India earlier adopted this ambitious target but realized it was not realistic given the size of its economy and later withdrew from this commitment.

In several countries, the governments have provided financial incentives and purchase subsidies to prospective buyers to bring down the upfront cost at comparable level to conventional vehicles. If we consider the fact that EVs usually cost 25% more than equivalent conventional vehicles, and in the absence of any purchase subsidies along with additional duties; EV penetration in Pakistan would most likely be gradual.

NEVP primarily outlines various incentives in the form of duty concessions for import of EVs, associated parts and chargers; duty-free import of plant and machinery for EVs for local assembling, and other benefits, including exemption of EVs from registration fee, annual renewal and sales tax. However, current incentives are offered to EVs with a battery capacity of 50KWh for passenger cars and 150 kWh for light commercial vehicles. This is rather unfavorable attempt and contrary to universal practice, where EVs with bigger battery capacity attract higher incentives. For example, in China, more incentive is given to higher range vehicles.

Description	Vehicle Type	Customs Duty (CD)	General Sales Tax	Additional Incentives
Completely Knocked Down (CKD) - EV Specific Parts Localized CD 25% Non-Localized CD 10%	Buses & Trucks	1%	1%	• 0% VAT at import stage • 0% Additional Customs Duty • 0% Regulatory Duty
	4W - Vehicles & SUVs	1%	1%	
	2W Motor Bikes & 3W Auto Rickshaw	1%	1%	
Completely Built Unit (CBU)	Buses & Trucks	1%	1%	• 0% VAT at import 0% Additional Customs Duty • 0% Regulatory Duty
	Passenger Vehicles & SUVs	10% till June 2022 & it would increase to 25% till June 2026.	1%	
	2W Motor Bikes & 3W Auto Rickshaw	50% of prevailing CD	1%	
Duty- and Tax-Free Import of Plant Machinery of EV Assembly and Manufacturing		0% CD 0% ACD 0% ACD		• Income tax exemption for auto part manufacturers for setting up manufacturing facility for EV related equipment
Import of EV Charging Equipment		1%		• 0% ACD • 0% RD

Table 3: EV Policy Incentives for Electric Vehicles, Source: EDB MoIP compiled by Author

CD = Customs Duty | GST = General Sale Tax | Source: EDB, MOIP - Author's compilation

Typically, a fully charged EV with a 50-kWh battery pack can cover an average distance of 250-270 km. Although, it is a decent driving range for short-range mobility, this limit implies that in real world conditions EV owners cannot travel between Islamabad and Lahore (370 km) on a single charge. This barrier can potentially discourage the prospective drivers from switching to EVs regardless of the lower running and maintenance costs.

It is important to recognize that at the initial stage, EV market requires a strong thrust in terms of favorable incentives, such as purchase subsidies to drive the momentum, with an eventual phase out of the incentives. While Pakistan may not be able to offer any significant purchase subsidies due to its current economic conditions, however, imposing unreasonable amount of duties could actually slow down EV penetration.

Under current incentives for EVs, an import duty at 10% has been levied on Completely Built Units (CBUs) initially for the first year of the policy and later it would increase to 25% till June 2026. CBU is an imported assembled vehicle that does not require addition of further components, and is ready to be used. Whereas, a completely knocked down (CKD) unit is the one which has been locally assembled in the country. However, some parts such as an engine, electronics and other components can be imported from the country of origin.

In order to encourage local production of EVs, CKD units have received highest incentives with marginal duty at 1% on EV specific parts at import stage. However, these incentives are restricted to EV parts only, such as electric motors, batteries, and auxiliary electronics whereas, non-EV specific parts would be taxed as per the existing tariff structure similar to conventional vehicles as stated in Table 3.

While the government has provided some decent concessions on duties and taxes on local manufacturing but for imported units these incentives are on a lower side, especially in the case of motorbikes, three wheels and four-wheel passenger vehicles. Thus, such measures can increase the price premium for imported units. This could serve as a barrier to EV adoption at an early stage due to higher purchase cost of imported vehicles at a point where locally assembled units do not exist in the market yet. It may be justifiable to incentivize imported EVs for scaling up the adoption at an early stage and gradually shifting these incentives in favor of automakers to encourage local production.

Interestingly, the customs duty on the import of buses and trucks has been kept at 1% for both CKD and CBU. Although it is a very lucrative incentive especially for the buses, which is a primary source of public transportation, but it is counterintuitive to invest in local manufacturing when one can import these vehicles at same duty and tax incentives that apply to CKD units. Thus, there is no point for automakers to consider going into local production for the buses and trucks.

In addition, NEVP underlines initiatives such as the green banking guidelines, private capital investments and other green financing opportunities to offer lower cost of capital for potential investors for concessional financing for setting up of EV Charging Stations and purchase of EVs.

In general, the NEVP has set the ground for promotion of electric mobility in the country and has laid down decent incentives for local manufacturing. However, there exists some gaps or limitations and it may require little more thrust for EV adoption in the form of more relaxed duties and taxes for imported units at least for an early stage of market development.

Moreover, during an initial phase the utilization of charging station is expected to remain low as there will not be enough vehicles on the road. Thus, it would be difficult for private sector to make an investment into charging infrastructure. Hence, public sources of funding could help address this gap with allocation of targeted subsidies during initial rollout of charging infrastructure, which will not only improve the confidence of prospective consumers in EV market, but it will also serve as demonstration effect for general public.

Global Lithium-Ion Battery Industry

A Lithium-ion (Li-ion) battery is an energy storage device that consists of interconnected cells for charging and discharging. The increase in EV sales has led to an increase in global demand for the Li-ion batteries needed to power the electric vehicles. Bloomberg New Energy Finance (BNEF) has ranked China at the top among the countries of the world most involved in the Li-ion battery supply chain in 2020, with Japan and South Korea in second and third place respectively. [10]

As of 2019, the global Li-ion battery manufacturing capacity was about 319 GWh per annum.[11] A large part of this capacity over 236 GWh is currently concentrated in China. One of the key reasons behind China's thriving battery industry is its secured access to raw materials; lithium, cobalt, nickel manganese and other rare earth materials. Many industry experts estimate that the demand for these minerals that come from earth crusts would skyrocket due to increase in sales of electric vehicles.

There are many types of Li-ion batteries and each has different characteristics, but EV manufactures prefer variants that have long lifecycle. Exhibit 3 below presents the manufacturing process flow of Li-ion cell manufacturing, which begins with refining the raw material to production and then end-use of a typical Li-ion battery. A Li-ion battery cell is made up of several components: a negative electrode or anode, a positive electrode or cathode, a separator and an electrolyte.

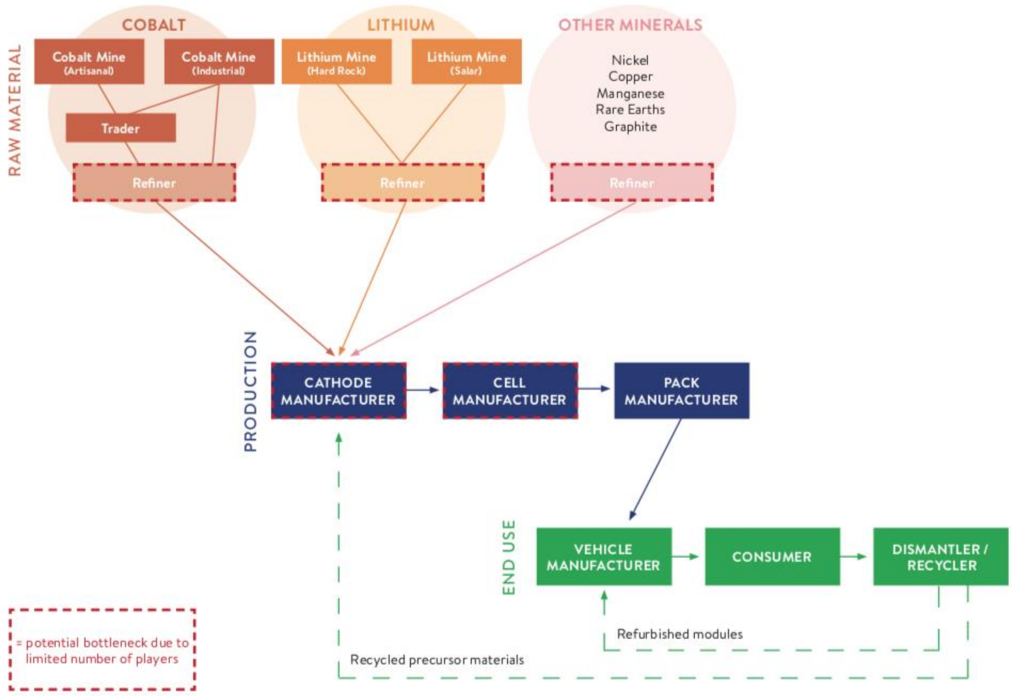


Exhibit 3: EV battery supply chain[12]

[10] Bloomberg New Energy Finance, Energy Storage 2020
[11] United States International Trade Commission https://www.usitc.gov/publications/332/working_papers/supply_chain_for_ev_batteries_2020_trade_and_value-added_010721-compliant.pdf
[12] Building a Sustainable Electric Vehicle Battery Supply Chain 2020, UC Berkeley

The chemical composition of the cathode defines the specific Li-ion battery type.[13] The most common Li-ion battery types used for EVs, characterized by their cathode composition are:

1. Lithium nickel cobalt aluminum (NCA), (used by Tesla)
2. Lithium nickel manganese cobalt (NMC), which has a higher energy density (used by BMW, Hyundai, Volkswagen, Nissan, and Mercedes-Benz)
3. Lithium manganese oxide (LMO) (used by Nissan and BMW)
4. Lithium iron phosphate (LFP), (commonly used in public transportation and suitable for 2/3-wheel EVs)
5. Lithium titanate (LTO), (used in public transportation for its fast-charging properties)

For Li-ion battery manufacturing, the underlying cell technology itself requires massive capital. Currently, a large-scale battery manufacturing plant could cost over US$ 100 million/GWh of capital expenditure.[14] The need for local manufacturing of battery packs would depend on the scale of EV adoption.

The two most important factors for Li-ion battery manufacturing are scale of operations and access to raw materials. The scale of operations plays an important role in battery manufacturing economics. For instance, lower capacity unit for battery manufacturing usually less than a GWh may not achieve the scale of economy and cost competitiveness.

Mineral	**Production in 2018**	**Total Production 2018 (Tonnes)**	**Reserves**	**Total Estimated World Resources**
Lithium	Australia 62% Chile 18% China 7% Argentina 7% Canada 3% Zimbabwe 2% Portugal 1%	95,000	Chile 52% Australia 17% Argentina 10% China 6% Canada 2% Zimbabwe 1%	80 million tonnes
Cobalt	DRC 70% Russia, 4% Australia 3% Philippines 3% Canada 2% Cuba 2%	148,000	DRC 51% Australia 17% Cuba 7% Russia 4% Philippines 4%	25 million tonnes (terrestrial) and 120 million (oceans floor)
Manganese	South Africa 31% Australia 18% Gabon 12% Ghana 7% Brazil 7% China 6%	18,900	South Africa 32% Ukraine 17% Brazil 17% Australia 12%	Large & irregularly distributed

[13] Alejandro González & Esther de Haan, SOMO the battery paradox, 2020
[14] https://www.greentechmedia.com/articles/read/Tesla-Giga-Factory-Update-4-to-5-Billion-Price-Tag-With-Production-Slate

Nickel	Indonesia 25% Philippines 14% Russia 14% New Caledonia 9% Canada 7%	2,400,000	Indonesia 24% Australia 22%, Brazil 12% Russia 8%	>117 million tonnes
Graphite (natural)	China 62% Mozambique 9% Brazil 8% Madagascar 4% Canada 3%	1,120,000	Turkey 30% China 24% Brazil 24% Mozambique 8%	>725 million tonnes (inferred)

Table 4: Production, reserves and estimated resources of key minerals used in Li-ion battery manufacturing. *(Source: The Battery Paradox by Centre for Research on Multinational Corporations SOMO, 2020)*

Raw materials, especially lithium and cobalt are scarce that are concentrated in a few countries and controlled by a few companies. For example, Argentina, Chile, and Bolivia - these three countries are called lithium triangle, which host over 75 percent of the world's lithium resources as illustrated in Table 4. The Democratic Republic of Congo (DRC) produces about two-thirds of the global cobalt. While in terms of manufacturing of Li-ion batteries, China dominates the industry by producing over 61% of global cathode materials and 83% of anode materials for EVs.

Pakistan is likely to play a limited role in the electric vehicle battery value chain. In the medium term, the Pakistani EV battery industry is expected to remain limited to battery pack manufacturing wherein the cells may have to be imported. Although Pakistan should explore the options for becoming an export base through industrial investments through China Pakistan Economic Corridor (CPEC) into mineral exploration for critical metals and cell manufacturing.

It needs to be further explored whether Pakistan possesses any reserves of lithium, cobalt or nickel or any other critical metals. The local production of these metals would determine the chemical composition for local production of Li-ion cell manufacturing. This step could drive the battery industry not only for the EVs but for the other applications, such as consumer electronics and power systems. Thus, in the near term, the local battery industry would depend on imports of Li-ion cells and stack them into battery packs.

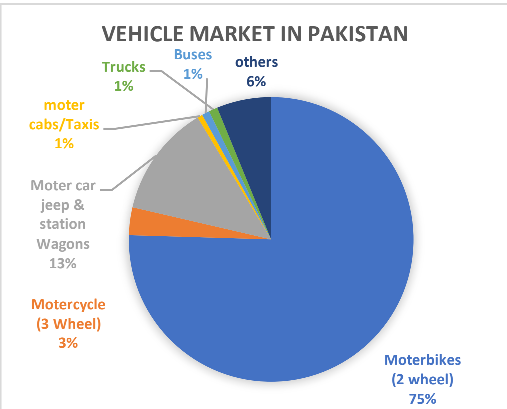
Chapter – II: Current and Future Landscape of Electric Mobility Market in Pakistan

Automotive Industry in Pakistan

Pakistan's automobile industry contributes (2.8%) to its GDP and 30 billion rupees to the national exchequer in terms of taxes and duties. With an extremely low penetration rate of approximately 13 cars per 1000 inhabitants and a rapidly growing urbanization rate of 40.5%[15], Pakistan has huge growth potential for its automotive market. With its low rates of vehicle ownership, EVs offer an opportunity to leapfrog the traditional ICE vehicles to more clean and sustainable transport.

Pakistan's automobile industry is one of the fastest growing economic sectors owing to growing domestic demand. The production and sales have grown by 171% and 172.5% respectively between 2014 and 2018[16]. However, data for 2019 shows a reduction in vehicles sold compared to the previous year attributed to the ongoing economic recession, which saw high interest rates along with a sharp depreciation of the exchange rate. All this led to an increase in the cost of vehicles and related components, which continued into 2020 as a result of the COVID-19 disruptions. Although, we assume the market would continue to follow the pre-COVID-19 trajectory.

The automotive trends demonstrate that the road transport sector in Pakistan has been growing at a significant pace. Over the last fourteen years, two- (2W) and (3W) three-wheel vehicles have recorded a very high annual growth rate at about 17%. While the passenger sedan cars and SUVs have grown with an average of 7% per year, and buses and trucks have recorded an average annual growth of 3%, during the same period.



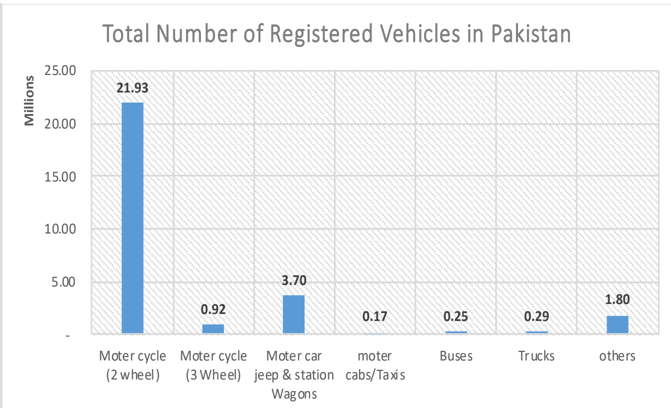


Exhibit 4 - Automotive Market in Pakistan[17]

The total number of registered vehicles has reached around 29 million in 2019[18]. Exhibit 4 presents the breakdown of the automotive market segment. Two-wheelers or motorbikes hold the dominant

[15] Strategic Analysis of the Pakistan Automotive Market, Forecast to 2025 https://www.researchandmarkets.com/reports/4733458/strategic-analysis-of-the-pakistan-automotive
[16] Sector Profile – Automotive and Auto Parts, Board of Investments
[17] Economic Survey of Pakistan 2019-20, (Statistical Appendix)
[18] Economic Survey of Pakistan 2019-20, Statistical Appendix – Transport and Communication.

share which represents over 75% of the total vehicles with an average annual sale exceeding over 2 million.

2W are an important consideration in the national EV policy, as they consume over 50% of the total petrol in the country. Consequently, higher sales of motorbikes have corresponded with higher consumption of petrol with 23%[19] year-on-year rise. If this trend continues, import bill of petrol could potentially shoot up to unsustainable levels.

Emerging Electric Mobility Players in Pakistan

Pakistan's automotive market has traditionally been dominated by Japanese automakers; Toyota, Honda and Suzuki. Globally, these Japanese automakers have had little interest in producing fully electric cars and rather their choice of cleaner technology has hydrogen fuel cell. Fuel cell technology is no doubt a better option in theory; but it lacks commercially viable solutions at the moment.

As part of this analysis, a market survey was conducted where we held consultative meetings with a number of key stakeholders, such as manufacturers, part suppliers, distributors and importer across the different vehicular categories. The major objective of holding these consultative meetings were to assess the current status and discern the future growth potential of electric mobility market in Pakistan. Consultative meetings with stakeholders revealed that private sector is keen on exploring this emerging electric mobility space, however, policy support from the government seems to be somewhat lagging.

At present, EV market in Pakistan is quite nascent and at a very early stages of its development. Despite the big hype for electric cars, we do not see enough momentum for passenger electric cars in the market. At the moment, there are only a handful of Original Equipment Manufacturers (OEMs) active in this space and largely the market focus has been on the 2W and 3W segments.

In Pakistan, 2W and 3W make up for over 78% of the overall market and are likely to be the first adopters of electric vehicles. These smaller vehicles are easier to electrify, since they need smaller and simpler batteries and are much closer to economic parity vs ICE. Majority of 2W existing OEMs are exploring this market and they would quickly switch to local production of EVs once the market has gained enough traction.

Despite the challenging economics, 2W and 3W segment has started showing some optimistic direction with emergence of new players, such as Jolta Electric, Crown Group and Sazgar Autos. These automakers have already started manufacturing 2W and 3W EVs locally.

The Sazgar Autos is currently the only local manufacturers of electric rickshaws in Pakistan. As part of our analysis, we believe that 3W segment has a tremendous potential for growth based attractive economic parity compared to ICE variants and hence, highest penetration levels can be achieved amongst other segments.

[19] Energy Year Book, 2020

In 4W segment, there has been a limited no of EVs launched in Pakistan till date. These EV launches have been limited to SUV category, primarily in the luxury passenger segment. 4W EVs have a significantly high upfront cost in comparison to ICE. At present, the market completely relies on imported units and a few automakers have launched their electric variants.

Currently, the 4W market is being driven by high end new market entrants with launch of premium models by Audi e-tron, BMW i3 and MG Motors. MG Motors has launched its ZS electric variant with local production in Lahore. In Pakistan, over 70% of cars are sold are at a price point of sub US$ 15,000 (~2.5 Million PKR). Therefore, widescale adoption in 4W category shall only take place when market witnesses launch of quality variants at affordable costs under 2.5 million PKR.

Currently, several gaps exist in the 4W EV market such as a limited number of products, high prices, insufficient driving range, low performance and an underdeveloped charging ecosystem. Given these impediments, the growth of EV 4Ws is expected to lag other segments, sales are expected to pick up once the existing gaps would be plugged.

In bus segment, market adoption will be driven on the account of public sector demand. Sapphires Group, which is a leading textile group has ventured with BYD Group in China and has launched a couple of electric buses in Karachi. Recently, Hitachi ABB Power Grids has entered into an agreement with Chinese electric bus manufacturer, Skywell and one of the largest bus operators in Pakistan - Daewoo to provide an electric bus solution to help Pakistan achieve its ambitious e-vehicle target and improve air quality in the country's cities.

Our interaction with various automotive stakeholders revealed that investors are actively exploring at the EV space as the next big opportunity to create value for their businesses.

Gauging the Total Cost of Ownership (TCO) of Electric Vehicles

Electric vehicles have a significantly higher upfront cost, as compared to ICE vehicles, largely on account of battery costs. On the other hand, the operating costs for an EV are much lower. The total cost of ownership (TCO) is the sum of all costs involved in the purchase, operation and maintenance of a given asset during its lifetime.

A comparative TCO analysis of electric vehicles and ICE vehicles can offer valuable insights for decision makers in various roles:

- For policy makers, the TCO analysis supports designing the right-sized charging infrastructure or financial incentives to promote EV adoption;
- For fleet owners, it provides an assessment of economic viability to support a business transition towards electric vehicles;
- And for consumers, the TCO analysis can support purchase decisions that are based on the lifecycle costs of owning and operating the vehicle.

We conducted TCO analysis for 5-year period for 2W, 3W and 4W passenger vehicles and 10-year period for buses. We consider here two fundamental cost aspects; capital expenditure (CAPEX) and operational expenditure (OPEX). CAPEX refers to upfront or purchase cost, while OPEX is the operations, maintenance and fuel cost, and new battery cost, if needed. Details of cost estimation of TCO assumptions are presented at Annex VI. A TCO analysis between ICE and EVs across different vehicle categories has been presented below.

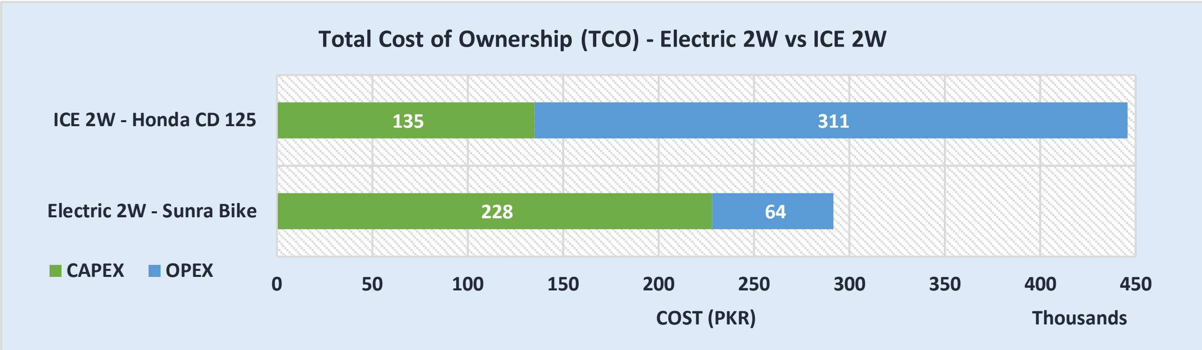


Exhibit 5: Total Cost of Ownership (TCO) - Electric 2W vs ICE 2W (High Speed)

ELECTRIC - 2W TCO comparison demonstrates that electric two-wheelers are already economically competitive. 2W are at TCO parity with ICE 2W for both personal and commercial use. The TCO for higher usage 2Ws is already attractive which is achieved at 50+ km daily usage. While the upfront cost in the case of a 2W is 50-75% higher than the ICE equivalent, and the operational cost per Km is almost 50% lower than that of an ICE 2W.

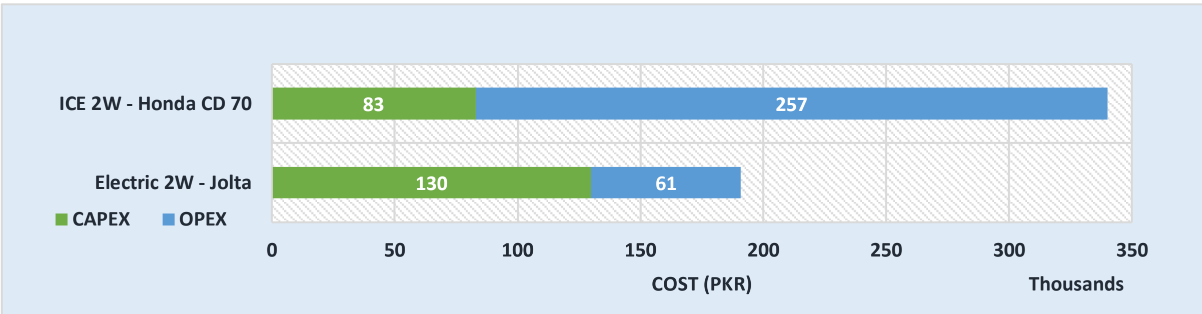


Exhibit 6: Total Cost of Ownership (TCO) - Electric 2W vs ICE 2W (Low Speed)

Exhibit 5 presents a comparison of Sunra Electric Bike and Honda 125 indicates 40% lower TCO. Exhibit 6 illustrates that Honda CD 70 TCO is about 50% higher than Jolta Electric Bike. Commercial use for electric 2W seems highly favorable with TCO advantage of over 50 km. For commercial use cases, with an assumed daily utilization of 80 km, TCO equation is very attractive for all electric models.

ELECTRIC - 3W The TCO comparison in auto-rickshaw segment indicates that electric-rickshaw is at TCO parity with ICE equivalent. While the upfront cost in the case of electric 3W is about 100% higher than ICE rickshaw, the e-rickshaws have a lower TCO, if daily running is more than 100 km. For an average daily usage case of 100 km, the TCO of e-rickshaw is 37% lower than ICE equivalent.

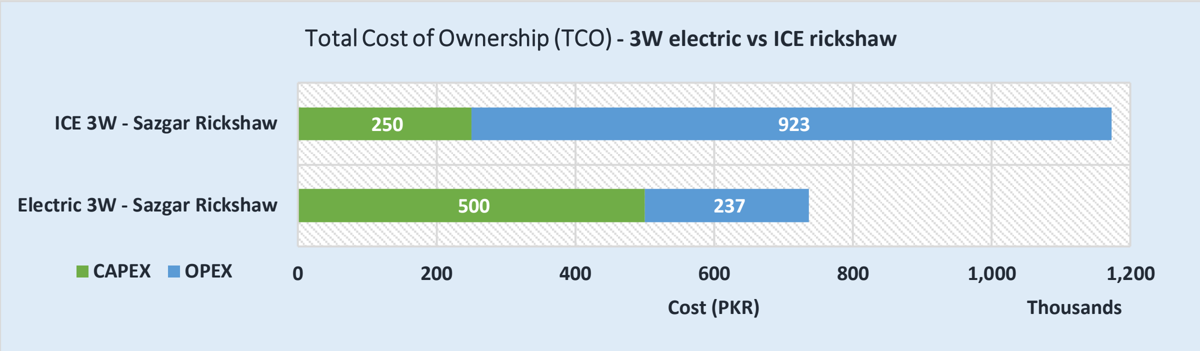


Exhibit 7: Total Cost of Ownership (TCO) - 3W electric vs ICE rickshaw

On an average, a rickshaw drives daily for over 200 kilometers and 250 kilometers in Lahore and Karachi respectively. With existing lithium-ion battery pack, Sazgar eRickshaw has a range of over 125 km. As a rickshaw is purely a commercial vehicle, charging it for more than a couple of hours after every 100 km may not be workable option. Hence, battery swapping is more suitable choice for three wheelers. Sazgar has been working with distributors to design a battery swapping station for their fleet.

Sazgar Autos is one of the largest manufacturers of three-wheel auto rickshaws in the country. Exhibit 7 demonstrates that with current incentives, Sazgar's electric rickshaw with lithium-ion battery pack costs over PKR 500,000 that is more than double of a conventional rickshaw which currently sells under PKR 250,000. One of the potential solutions to reduce this cost differential is to sell electric rickshaws without a battery pack. One of the considerations is to rent out the interchangeable batteries at their designated battery swapping stations.

As the upfront cost is extremely high, an average consumer is still reluctant to switch to an EV. Although large fleet operators may quickly recognize the cost benefits in comparison to conventional rickshaws. The company has already received orders from large fleet operators, including Metro for eRickshaws.

ELECTRIC - 4W - Electric cars can be economically viable for commercial fleet operations but TCO equation is not yet attractive for personal use case. TCO analysis demonstrates that electric cars are economically viable for commercial fleets with high daily utilization.

We make a comparison in the premium 4W crossover category between MG ZS EV and MG HS ICE in Exhibit 8, which highlights that TCO parity can be achieved of an electric and an ICE variant based daily usage of 50 km.

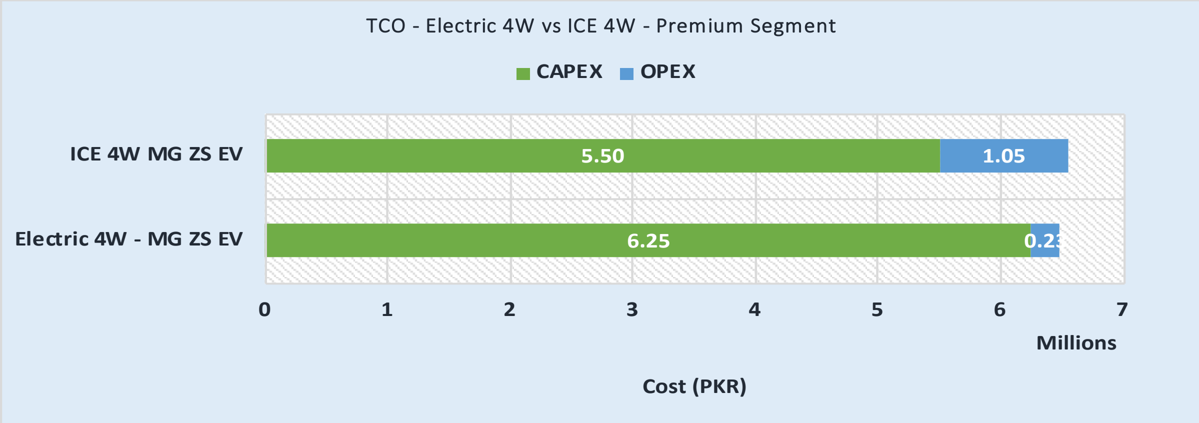


Exhibit 8: Total Cost of Ownership (TCO) - Electric 4W vs ICE 4W - Crossover Segment

Currently, the market has not yet introduced any 4W passenger sedan cars. However, for the sake of TCO comparison we compare Hyundai Ioniq Electric with Honda Civic 1.5 Turbo in premium sedan car segment. TCO analysis indicates 14% higher TCO for electric variants as demonstrated in Exhibit 9. Thus, electric cars for personal use would require financial incentives to be economically viable.

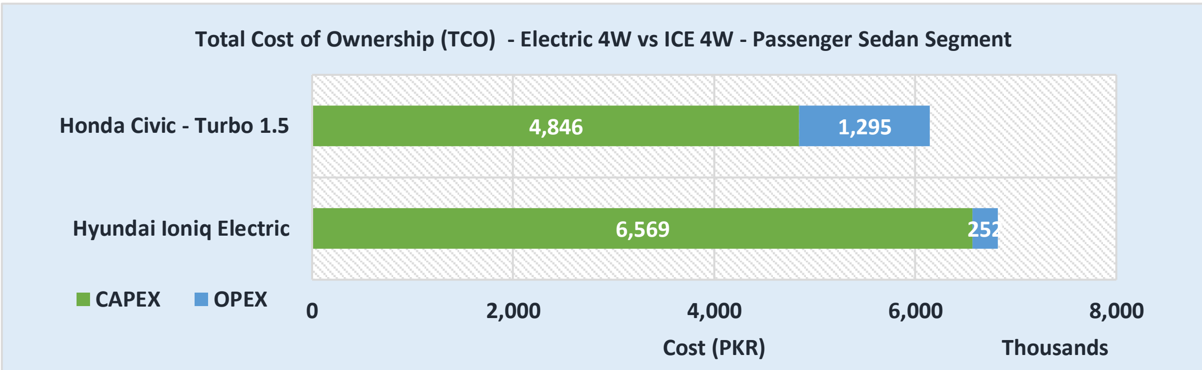


Exhibit 9: Total Cost of Ownership (TCO) - Electric 4W vs ICE 4W - Passenger Sedan Segment

Detailed technical and cost assumptions are provided at Annex VI.

ELECTRIC BUSES have a very high upfront cost differential due to the large size of the battery. TCO parity can be achieved at the daily usage of over 250 km. However, we believe that the adoption in buses would be based on support from government driven demand in the form of additional purchase subsidies and not on TCO parity. For electrified public transport fleets to be economically competitive, electric buses would need higher utilization to lower capital costs.

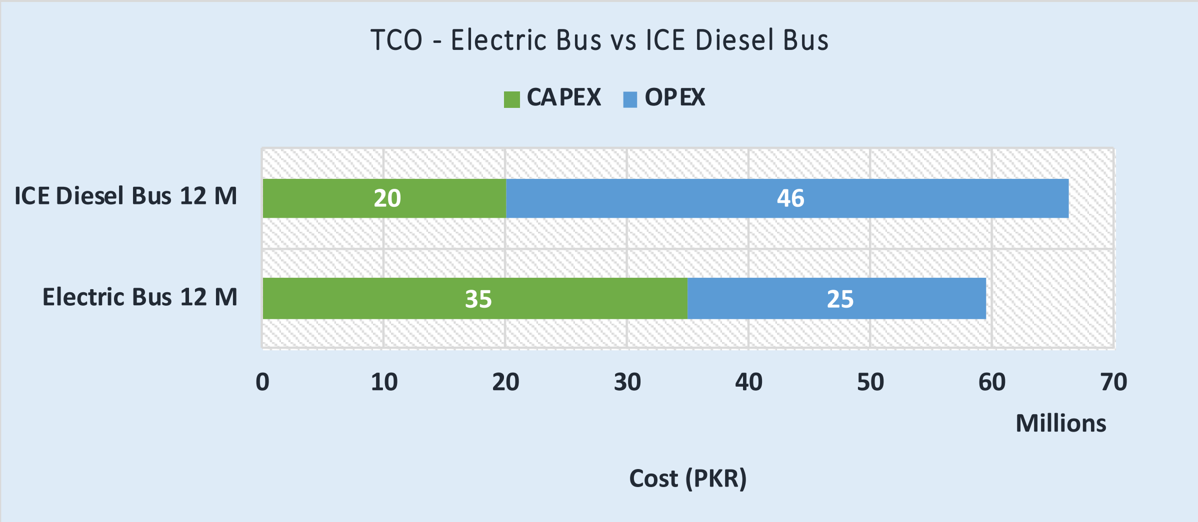


Exhibit 10: Total Cost of Ownership (TCO) - Electric 4W vs ICE 4W - Passenger Sedan Segment

Higher Vehicle Utilization

The TCO analyses reveals that higher vehicle utilization results in a steep decline in TCO per km for electric vehicles. Lower fuel and maintenance costs result in greater savings for electric vehicles as vehicle utilization increases across all vehicle segments. For every extra kilometer driven, the TCO per km for EVs shows a greater reduction in comparison to ICE vehicles. This means that higher daily utilization and/or a longer vehicle holding period can deliver greater savings for EV users — even after accounting for battery replacement, particularly in the case of electric buses.

The biggest driver for the upfront cost and the TCO, is the cost of the battery. We expect that the cost of batteries would continue to drop, whereby the TCO equation would become even more attractive in favor of EVs and that would determine the inflection point for rapid adoption of EVs.

While the policy incentives can create momentum for EV adoption, the eventual large-scale adoption will only take place when EVs make economic sense to the end-user. For a Pakistan's market, retail users and individual buyers are very sensitive to the upfront or purchase cost. Thus, the large scale EV adoption in Pakistan would be contingent upon not only on the TCO, but also on the upfront cost. While for the commercial applications – where vehicles run for larger distances over their lifetimes are already at or are very close to parity.

Factors that will drive EV adoption in Pakistan

The rate and degree at which EV penetration takes place Pakistan is not an easy or straightforward to contemplate. However, there are four critical factors that will drive the EV adoption in the country over the next decade – policy support, global battery costs, charging infrastructure and localization of supply chain.

Policy Support

Government of Pakistan seems to be extending a reasonable amount of support to the growth of electric mobility ecosystem by providing a range of concessions and incentives on taxes and duties for local manufacturing and imports. However, these incentives may not be good enough to generate the required traction in the market.

EVs are significantly more expensive than ICE vehicles in terms of the upfront cost and TCO argument is slightly difficult to build for a retail or individual customer. Hence, regulatory duty and tax concessions alone would not be able to drive the market for large scale adoption – that will happen only when upfront cost is significantly reduced, and economic parity is achieved in favor of EVs.

Hence, the NEVP may be revised to promote EVs with some targeted purchase subsidies to reduce the price premium on upfront cost of EVs. With current incentives, it seems that EV adoption is expected to remain low in Pakistan because of unfavorable economic parity.

Battery Cost in Global Market

Battery cost is the single biggest constraint for EV economic parity which hinders the large-scale market penetration. Decline in battery cost is an important driver for EV adoption as it significantly affects the upfront cost and subsequent TCO parity of the EVs. As part of this analysis, we wanted to assess the impact of global battery cost on local supply chain to determine the upfront cost for the end consumer. A key barrier to EV adoption, particularly in Pakistan's cost-sensitive automotive market would most likely be the higher purchase price than equivalent ICE models.

The market survey indicated that with existing tariff and duty structure, 2W EV with lithium batteries costs over 130,000 PKR that is more than double of an equivalent combustion engine which currently sells under 65,000 PKR. At this price point, it is extremely difficult for prospective buyers to switch to EV owing to high upfront cost despite attractive or favorable TCO argument. This higher differential cost is mainly due to lithium batteries. This has serious implications for the retail users and individual buyers who are especially sensitive to the upfront cost.

Although, globally the battery costs have declined by around 85% in the last decade. The prices are further expected to decline. While looking at the global forecasts, EVs are likely to achieve a price parity with conventional ICE vehicles in the medium term by 2025. This is in line with the forecast by the Bloomberg New Energy Finance (BNEF) that suggest Li-ion battery prices are expected to come down to US$100/kWh in 2024.[20] This decline in cost is attributable to advances in battery and power component technologies and growing economies of scale that is likely to push the EV prices further down.

The price point of US$100/kWh is being considered as a tipping point, where consumers will no longer consider electric vehicles as costlier options. Under such conditions, adoption would be much quicker and increasing number of consumers are likely to switch to EVs due to favorable economics. Thus, we believe that decline in battery prices is fairly certain, however slower decline will further affect the market penetration, especially, in the 4W segment.

[20] S&P Global Market Intelligence – Lithium-ion battery innovation
https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/as-battery-costs-plummet-lithium-ion-innovation-hits-limits-experts-say-58613238

Charging Infrastructure for Pakistan's Unique Needs

Globally, EV adoption has been supported by widespread charging infrastructure development. Pakistan's EV market will have own unique requirements for charging infrastructure. 2W and 3W constitute for over 80% of the overall market and these two segments are likely to be the first adopters of electric vehicles.

Our interaction with EV market players suggested that 2Ws can be easily charged at home and most of them run less km/day than what the battery capacity allows, making range anxiety a lesser of a problem. Development of residential/private/ commercial infrastructure will require creating awareness, and it would necessitate city level policy support and some innovative business models.

In case of 3W, which is entirely used for commercial purposes, it would typically require an additional charge during the day considering the fact they run for longer distances. This additional charging has critical implications for rickshaw drivers as the time it takes is the opportunity cost for not running the vehicle. Therefore, for 3W category, battery swappable model would work better as opposed to traditional charging method. Battery swapping would enable electric rickshaw drivers to avoid 3-4 hours of down time thus, increasing their earning potential.

Battery swapping model eliminate the need for long charging time, addresses range anxiety, high upfront cost for the EV owners. The critical challenge for battery swapping is to ensure standardization of batteries and operate in a closed loop environment. In addition, as more EVs enter the Pakistani market, the challenge of sustainable end-of-life practices for battery disposal and recycling also arises. At present, Pakistan has very little recycling infrastructure, implying that batteries are discarded without proper disposal mechanism in place. Given this case, a coherent recycling policy for batteries is the need of the hour.

In cities or certain locations where a considerable size of the urban population lives in high-rise buildings, where parking facilities are either poor or non-existent, the need for charging infrastructure is evident.

In passenger cars, most of EV charging is done at home on slow AC chargers and the rest is supported by the public charging infrastructure. However, residential charging in Pakistan, especially, in urban areas is tricky due to the lack of proper parking arrangements. Thus, in order to encourage the 4W EV adoption, development of public charging infrastructure would play a key role. Similarly, DC Fast Charging stations along highway corridors, including motorways for enabling long range travel.

Electric busses come with very large battery capacity that need DC fast chargers to charge them quickly during the operational hours or even during the night. While depots are perfect places to charge these buses at night, each depot would have a considerable size of buses and if a significant number of buses need to be charged together, the capability of the grid is an important aspect to be considered.

Localization of Supply Chain

Localization of the supply chain is critical from the perspective of reducing the cost differential between EVs and ICE vehicles. A well-developed indigenous supply chain could help reduce the cost of electric vehicles.

In short term, EV manufacturing in Pakistan would largely be contingent upon imported components. Currently, the scale of EV adoption is too small, which does not justify the localization of critical components. However, going forward, it would be important to develop a road map for scaling up the EV market with vibrant domestic supply chain.

Lithium-ion battery cells, which are the highest cost component in EVs, are also the most difficult to indigenize due to reliance on critical earth metals. Thus, Pakistan is likely to play a limited role in the electric vehicle Li-ion battery value chain. In medium term, the Pakistani EV battery industry is expected to remain limited to battery pack manufacturing wherein the cells may have to be imported.

It needs to be further explored whether Pakistan possesses any reserves of lithium, cobalt or nickel or any other critical metals. The availability and local production of these metals would determine the chemical composition for local production of Li-ion cell manufacturing. This step could drive the battery industry not only for the EVs but for the other applications, such as consumer electronics and power systems. Thus, in the near term, local battery industry would depend on imports of Li-ion cells and stack them into battery packs.

Electric motor and controllers are also challenging to localize due to their reliance on rare earth magnets, which could become a bottleneck to domestic motor industry. However, for small motors for light electric vehicles should be easier to manufacture locally. Large motors are technologically intensive and could take a longer time to be localized in Pakistan. Although, controllers are technologically sophisticated but they can be manufactured locally if adequate investment is made in technology.

Battery Management Systems (BMS) and Balance of Power (BOP) technology, on the other hand, are relatively easier to develop locally. Other components, such as chassis, bodies and drivetrain are closer to the core strength of local industry especially for 2W and 3W market. Thus, there is a likelihood that their manufacturing will get localized rather quickly.

Pakistan should explore the options for becoming an export base through industrial investments through China Pakistan Economic Corridor (CPEC) into mineral exploration for critical metals, cell manufacturing and production of critical components for EVs.

EV penetration in Pakistan based on TCO Equation

Decline in battery price globally is the most important driver for mass scale adoption of EVs. As prices may continue to fall, the role of policy would be critical in ensuring that Pakistan does not lag in EV adoption. Policy support and battery cost are the two main drivers that will decide how adoption takes place in Pakistan over the next 10 years. Development of local supply chain and public charging infrastructure are two supporting conditions that will have a further impact on the extent of EV adoption in the country.

2W – Electric Bikes: 2W market is highly sensitive to pricing. Thus, in addition to favorable TCO, lower purchase cost is essential for mass adoption of electric 2Ws. The total cost of ownership of electric 2W is already lower than ICE equivalents. However, as battery prices may drop, it is expected that a reduction in upfront cost will further drive interest among customers. The point of inflection for mass adoption of electric 2W is assumed to be reached by around 2023 with Li-ion battery prices falling to US$ 140-150/ kWh. Customers also need an access to good financing opportunities to buy EVs, availability of which is limited currently.

2W fleets are likely to shift to EVs much more rapidly. Delivery fleets like DHL understand the TCO benefits fairly well and they are already charting out plans to go electric. For fleets, considering massively low operating costs, not going electric would be a costly mistake.

3W Electric Rickshaws are likely to rapidly shift to benefit from a favorable TCO equation. A shift from ICE to electric rickshaw makes complete sense right now from TCO standpoint. However, higher upfront costs could reduce electric adoption in the rickshaw market at a larger scale. Fleet based 3W operations such as Metro Cash & Carry have already started exploring the electric market. Sazgar Autos has already started manufacturing e-rickshaws locally with imported lithium-ion packs. However, limited avenues for financing seem to be a major barrier in 3W segment.

4W passenger electric cars – In Pakistan, over 70% of cars are sold are at a price point of sub US$ 15,000. At present, an electric car with the same price tag usually do not match the performance of an ICE car. ICE equivalent cars have a much bigger battery, even a 40-kWh battery pack makes a significant difference in the purchase cost. Whereas, in the case of personal use, which usually have lower running over their lifetime; the TCO argument does hold true in the favor of electric cars.

However, fleet operators on the other hand would be incentivized to go electric. On a TCO basis, electric cars are cheaper for average daily running in excess of 120 km. We believe the tipping point for electric cars is expected to come around 2025-26 at battery prices of around US$ 110/kWh.

Overall, the market for luxury vehicles such as Porsche, Range Rovers and Audi is quite small in Pakistan. However, there is some momentum for high end electric vehicles owing to reduced duty structures on EVs. Due to this this reason, Porsche and other high-end auto importers are aiming at introducing their imported electric variants.

For instance, Porsche Taycan, its petrol version would normally cost over PKR 80 million in Pakistan whereas their same electric variant with reduced import duties would cost around PKR 30 million. For luxury segment, charging infrastructure is not really a big concern, as most of these high-end EV owners have an access to dedicated charging docks at homes. Though, they would still need to plug in their vehicles for super-fast charging at 150 kW at highway and motorways.

Electric Buses - At current battery prices, the cost differential between an electric and diesel bus is significant. Although, electric buses compete with ICE variants on TCO basis based on 10-year period, however high upfront cost would still be a significant barrier and time period to breakeven would be much longer. Thus, bus sales are not expected to increase soon without well planned government support in the shape of procurement subsidies.

For electrified public buses to be economically competitive, they would require higher utilization or financial incentives to lower capital costs. Electric buses are expected to come at TCO parity with ICE equivalents at batteries prices of US$ <100/kWh.

Chapter – III: EV Charging Infrastructure for Pakistan's Unique Needs

Bloomberg New Energy Finance predicts that by 2040 sales of EVs will overtake those of combustion engine vehicles. Global experiences demonstrate that many factors influence the EV penetration. However, two most important determinants are the purchase cost of an EV and availability of charging stations across the country.

Unlike a combusting engine vehicle, which can be refueled within minutes at a petrol station, EVs need to be recharged, and this charging process is much slower than refueling. This is one of the major points to consider towards EV adoption and it requires a behavioral shift among EV owners. Fast, easy and affordable access to charging infrastructure plays a predominant role in removing the psychological barrier among potential consumers, termed as "fence sitters" who wait and explore the market for right conditions to make a purchase decision in favor of EVs.

Worldwide, the charging infrastructure presents a "Chicken and Egg" dilemma. On one hand, the investors are reluctant to invest in this new market, and on the other hand, consumers are uncertain to adopt EVs without widespread and reliable charging infrastructure. Hence, success of this transition depends on how quickly the adequate charging infrastructure can be put in place to drive the EV adoption.

Furthermore, charging infrastructure integrates mobility with electricity sector, and has the potential to transform both the transport sector and electricity distribution. Thus, power distribution companies have a tremendous role to play for uptake of electric mobility in Pakistan.

Understanding the EV Charging Technology

Typically, an EV Charging Stations consists of one or more Electric Vehicle Supply Equipment (EVSE). EVSE consists of multiple parts, including connections from the distribution system to the EVSE meter and from the meter to the charging infrastructure, and the EV charger itself. It basically controls the energy supply to an EV. A single EVSE may have multiple connectors but usually only one connector can be used at a time. There are two fundamental methods of charging an EV; via Alternating Current (AC) or Direct Current (DC).

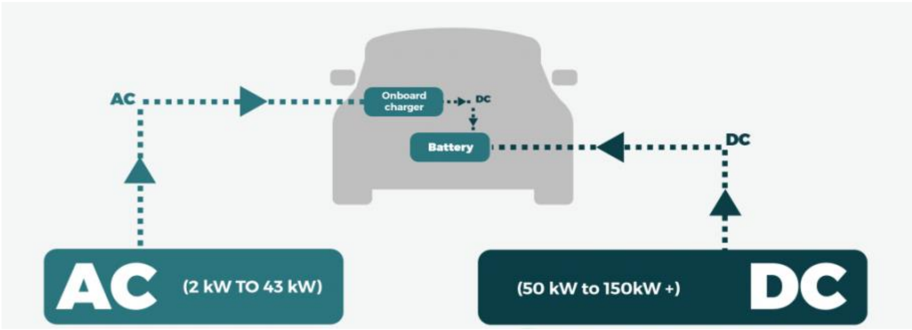


Exhibit 12: AC versus DC Charging - Schematics[21]

[21] WallBox, **EV Charging Current: What's the Difference Between AC and DC?**

Charging equipment or EVSE comes are characterized by two main categories. The first category is "Level 1" and "Level 2", which use Alternating Current (AC), and it draws electricity directly from the local distribution network. All EVs essentially carry an on-board inverter to convert AC power to direct current (DC) because the battery can only accept the DC current.

The second category is the "Level 3" and above, which uses DC charging. It does not need for an inverter and charges the battery directly and can therefore deliver higher levels of power. Level 1 is mostly suited for residential charging. Commercial chargers usually operate at Level 2 and Level 3. EVSE can be standalone devices, or stations comprised of multiple chargers. Exhibit 12 illustrates the process of charging with AC and DC chargers.

AC Level 1	AC Level 2	DC Fast Charge
Charging Loads	Charging Loads	Charging Load
2 to 3.3 KW	3.3 to 22 kW	50-350 KW

Exhibit 13: Levels of Electric Vehicle Charging[22]

Level 1 and 2: Alternating Current

Depending on the range of delivered power that are supported by EV chargers, they are classified into three levels as demonstrated in exhibit 13.

Level 1 corresponds to a single phase 220V AC plug – draws up to 3.3 kW mostly suited for residential charging. Level 1 is connected to standard wall socket, and requires no additional circuit, aside from the adapters required to connect the EV to the socket. Level 1 charging can be used anywhere, although in practice it is done primarily at homes.

Level 2 refers to the three phase 220-240 V AC and ranges between 3.3 kW and 22 kW. Worldwide, the most public charging poles are installed at Level 2 and these are ideally suited for commercial, businesses and workspaces. Most of the Level 2 chargers operates at 7 kW, firstly, because the onboard inverter on most existing EVs cannot handle significantly more than this level[23]. Secondly, higher capacity Level 2 charger at 22 KW would require the installation of more expensive and higher capacity circuits.

https://wallbox.com/en_catalog/faqs-difference-ac-dc
[22] **Kristi Brodd**, "Find Charging Options for Your Electric Vehicle, Carolina Country", (2017) https://www.carolinacountry.com/your-energy/energytech/know-charging-options-to-keep-your-ev-rolling
[23] Henry Lee and Alex Clark, "Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption" Harvard Kennedy School (2018), https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf

Level 3 and above: Direct Current

Level 3 charging corresponds to dedicated quick charging stations using high voltage DC, typically rated over 50 KW. Level 3 - direct current charger bypasses EV's onboard inverter to charge the battery directly, it can deliver much higher levels of electrical power. This type of charger is commonly referred to as a Direct Current Fast Charger (DCFC) and is used only in commercial locations.

For the purposes of this report, we classify DCFC charging into following three categories[24]:

- Level 3 fast charging corresponds to 50 kW
- Level 4 fast corresponds to 150 kW
- Level 5 (ultra-fast DCFC) corresponds to 350 kW

Charger Type	Current Type	Power Delivered (kW)	Time taken to replenish daily usage 50 km (10 kWh)	Time to Taken to Charge 200 km	Range Added per Minute (km)
Level 1	AC	1.5	6h 40m	26h & 40m	0.13
Level 2 (Standard)	AC	7	1h 26m	5h & 43m	0.58
Level 2 (Maximum)	AC	22	27m	1h & 49m	1.83
Level 3	DC	50	12m	48m	4.17
Level 4	DC	150	4m	16m	12.50
Level 5	DC	350	2m	7m	29.17

Exhibit 14: Charging characteristics based on various charging levels

Exhibit 14 presents each charger type, its power rating in kW, the time it takes to refill the expected average daily usage of 10 kWh, the time taken to charge 200 km of charge (i.e., 40 kWh), and the km of range added per minute of charging. Charging time is assumed to depend entirely on the power rating of the charger, although in practice, technical limitations on the battery, electrical supply, and inverter capacity (for AC charging) can add time to the process. The above time estimation assumes that the rate of charging is linear. This demonstrates that even with ultrafast DC 350 KW charger, charging an EV will take more time than refueling an ICE vehicle.

EV Charging "Modes"

The mode of an EV charger is defined to decide its charging application and level of communication between the charger and the vehicle. Globally, there are four modes characterized by level of safety features as presented in exhibit 15 and as defined by IEC standard:

- **Mode 1 (AC Charging):** Uses a standard domestic socket-outlet and does not use any safety or control feature. Since there is no protection circuitry preventing accidents, it is considered unsafe by most automakers and offers "low" level of safety.
- **Mode 2 (AC Charging):** It also uses a domestic socket-outlet, but it employs an in-cable protection device and a power level control that protects the user and the vehicle. This mode

of charging is well-suited for longer period of charging at home or in office. Since the mode 2 employs a protection mechanism, it is considered to have an acceptable level of safety features.

- **Mode 3 (AC Charging):** A dedicated EV supply equipment (EVSE) and a charging cable assembly is employed and uses specific EV socket-outlet and plug with control and protection function installed. This mode is ideally suited for malls, petrol stations, parking areas, etc.
- **Mode 4 (DC Charging):** A dedicated external EVSE is used with an AC/DC converter providing direct current with power levels starting at 50 kW (mainly for parking spots along highways, motorways or places where the driver is in a hurry to recharge its car battery).

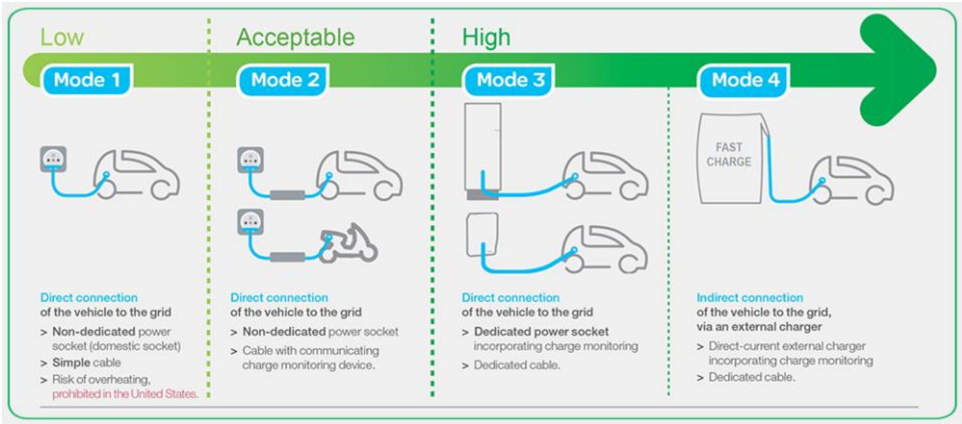


Exhibit 15: Conductive EV Charging Modes as defined by IEC standard - Source: DVK Consultants

Charging Plugs or Connectors

A charger type typically refers to the output socket and the connector used by a charger. It also includes the communication protocols between the charger and the vehicle which are required for various charging modes. Globally, there is a wide variation between the different types of sockets due to regional needs and discretion of car manufacturers.

Exhibit 16 illustrates popular types of charging ports or connector guns being used by electric car manufacturers all over the world. Currently, there are three ports/connectors for AC charging and four for fast DC charging as listed below:

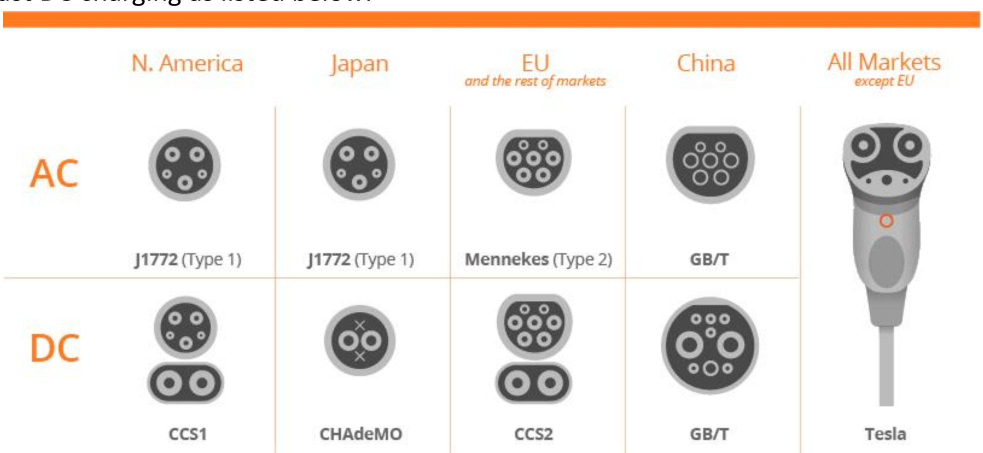


Exhibit 16 - Types of Charging Plugs or Connectors (Source: *EnelX*)

- **AC Type 1** is common for American vehicles, it is a single-phase plug and can charge at a speed of up to 7.4 kW. It follows the North American SAE J1772 standard.
- **AC Type 2** is standard for European and Asian vehicles from 2018 onwards, it can operate both at single and triple-phase plug and can charge at a level of up to 43 kW. It follows IEC 62196 standard.
- **CHAdeMO** – a Japanese standard - it was the first widespread technical standard for DC fast charging developed by a Japanese consortium. Nissan and Mitsubishi use this connector and allows for high charging capacities as well as bidirectional charging.
- **Combined Charging System (CCS)** - 1 commonly referred as Combo 1, which is preferred by US car manufacturers, and **CCS 2 or Combo 2** is commonly used in Europe (BMW, GM, VW, and other carmakers) for DC fast charger.
- **GB/T** – Standard for Chinese electric car manufacturers for both AC and DC charging.
- **Supercharger** – Standard connector for Tesla for both AC and DC charging.

Lack of harmonization among EVs and charging technology standards is one of pain points towards scaling up of EV charging infrastructure. The existing framework for compatibility for charger ports is little complicated as discussed in a later section.

Charging connector or plug is suitable for Pakistan's market

Having multiple standards is a waste of both time and resources because it creates interoperability issues, uncertainty and provides unclear market signals especially to prospective EV owners and charging infrastructure. Pakistan has to adopt a formal standard for EV charging system. Worldwide, Combined Charging System 2 or (CCS 2) which is commonly used in the Europe - seems to be winning the charging industry.

In addition to Europe, many other nations, including Greenland, Australia, Brazil, South America, South Africa and Saudi Arabia have officially adopted CCS 2 standard. Due to its universal characteristics, it can handle DC fast charging, single phase AC and three phase AC. It is very likely that many other countries would continue to adopt CCS 2 as their national standard. CCS 2 operates at 220 Volts and 50 hertz, which is identical to Pakistan mains electricity and as the name indicates it integrates both DC and AC plugs into single charging port.

CCS 2 has a dual use capability for both AC and DC charging using the same charging port. Due to this unique and simple architecture, today more car manufacturers supply EVs with CCS 2 for all regions than any other charging standard. For this very reason, type 2 for AC and CCS 2 for DC could be well suited to Pakistan's market. **If CCS 2 standard is adopted, it may provide much needed clarity for OEMs, consumers and charging equipment suppliers and help boost seamless uptake of EVs in the country.** Exhibit 17 demonstrates that - European CCS (Type 2 / Combo 2) is prevalent in major parts of the world, whereas CCS Combo 1 is exclusive to the North America**.**

EV Charging Summary Snapshot

PARAMETER	SLOW	MEDIUM	FAST
LEVEL	Level 1	Level 2	Level 3
AC OR DC	AC	AC	DC
POWER RANGE	<3.3 KW	3.3-22 KW	50-350 kW
MODE	Mode 1 and Mode 2	Mode 3	Mode 4
TYPE	Domestic sockets	IEC Type 1 IEC Type 2	CCS Combo 1 (US) & 2 (EU), CHAdeMO (Japan) GB/T DC (China) and Tesla connector
UTILITY	Residential	Residential/Work/Commercial	Transport Corridors - Motorways
VEHICLES	2W, 3W, Cars	2W, 3W, Cars	Cars and Buses

Source: Author's Compilation

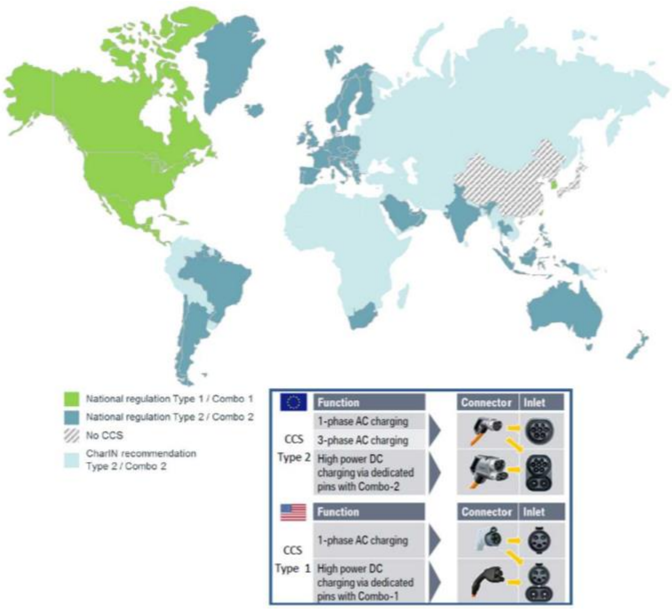


Exhibit 17 - Region-wise EV charging ports[25]

EV Charging Behaviors or Pattern

The discussion around the chicken and egg dilemma of what comes first - the EVs or charging infrastructure – has been under considerable debate towards achieving a shift to e-mobility. It is important to note that charging infrastructure is an important element for uptake of EVs, as it builds consumer confidence and removes psychological barrier to range anxiety. Though, charging infrastructure alone would not accelerate the transition to electric mobility. We believe that the industry also needs to supply a diverse range of EV products at affordable price point. These conditions would have to be essentially met for the electric mobility to take off.

[25] InsideEVs - https://insideevs.com

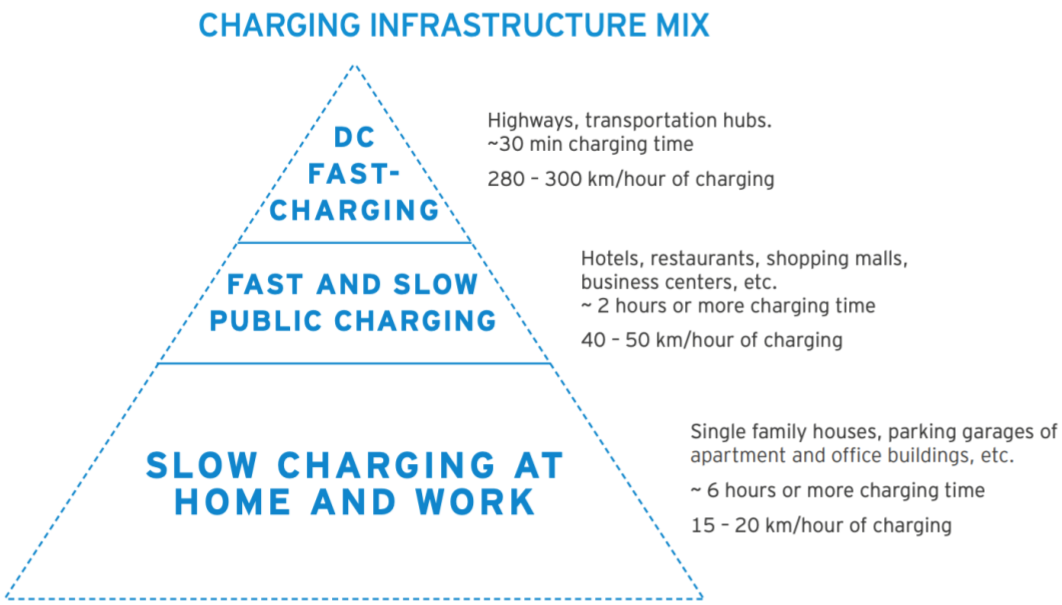


Exhibit 18 - Charging Infrastructure Pyramid[26]

Many other factors influence the EV market penetration, such as overall automotive market, policy incentives, purchase subsidies, buying capacity of consumers and emission targets. Considering many dynamic variables of electric mobility, it is quite a challenge to ascertain the EV penetration and the corresponding need for charging infrastructure.

Nevertheless, one can draw evidence and insights from global experiences and establish a minimum charging infrastructure criterion for Pakistan. While drawing global experience, it is important to recognize the charging patterns and behaviors in order to determine the adequate size and type of charging infrastructure. EV penetration in Pakistan would most likely be gradual unless the global Li-ion battery prices drop significantly and there is a price parity between and EV and ICE vehicle. Owning an EV is behavioral and lifestyle shift and does not follow conventional approach of refueling a car at a petrol station in a matter of few minutes. Thus, it is not plausible to draw parallels between an EV charging station and petrol station.

It is plausible to assume that those early adopters who are currently buying EVs, they could charge their vehicles at home overnight. But as the EV go mainstream and purchase cost continues to go down, a greater number of lower- and middle-income consumers would likely shift towards EVs; this would create the additional need for public charging stations, as home charging may not be an option for them.

For adoption of EVs in Pakistan at the early stage, access to home charging would the most important factor in encouraging consumers to purchase EVs. Evidence from market leaders indicate that the bulk of the charging takes place at home using Level 1 slow chargers overnight at rated power less than 3.3 KW. Workspaces is the second most suitable option for recharging where a vehicle is typically parked over five hours. Charging at workspace takes place at Level 2 AC charging within a power range of 3.3 and 22 KW. At the early stage, most charge points at workspace could be installed at 7–11 kW.

[26] Electric Vehicle Charging Infrastructure – www.cleantechnica.com

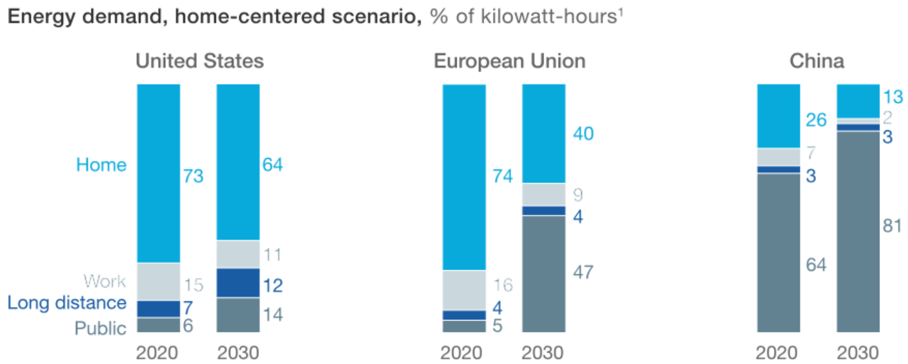


Exhibit 19 - Charging Segments in the US, EU and China. Source: Mckinsey 2019

Third most frequent charging choice after home and workplace is publicly accessible chargers to be located at commercial facilities, commonly referred as destination points, such as supermarkets, hotels or restaurants. It would be ideal to have chargers with capacity range of 11-22 kW AC points at these locations, and/or CCS 2 and CHAdeMO DC fast chargers.

Publicly accessible charging is also an important consideration for apartment complex and for those who do not have access to home or workplace charging. Major locations for these charging stations should be medium-stay "hot spots" such as:

- Shopping centers
- Restaurants
- Coffee shops
- City centers
- Gyms/sports
- Major government administrative offices

DC Fast Charging stations along highway corridors, including motorways are extremely important for long range travel. These fast-charging stations should also be installed at major entry/exit point into a city. These stations typically operate at Level 3 with minimum power capacity of 50 kW, but more ideally 100—150 kW. Current technology for Level 3 can offer charging capacity up to 400 KW.

Exhibit 19 demonstrates the current EV charging deployment in the US, EU and China - segmented by home, work, public and long-range travel. For the US and EU, the bulk of charging take place at homes and it will potentially shift towards public charging options over time. However, in China - due to its structural limitations of highly dense urban cities and large apartment communities, public charging option is the most preferred choice rather than home charging. Given this scenario, for densely populated cities like Karachi, where apartment living is common, availability of public charging stations would be an important consideration to drive the EV adoption.

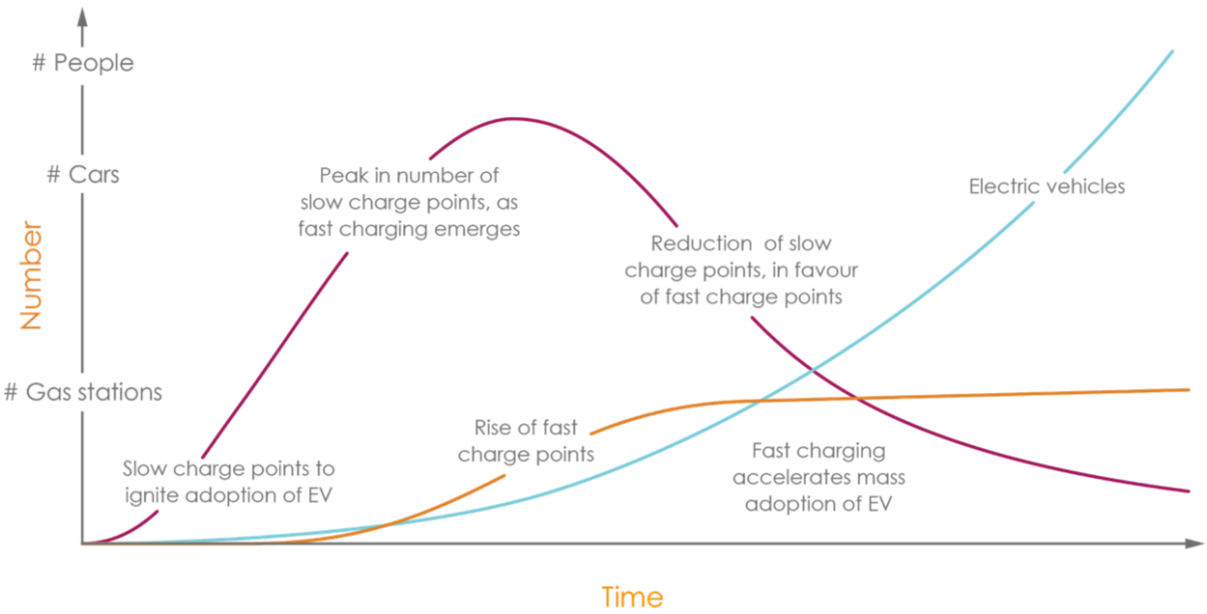


Exhibit 20: The relationship between the number of EVs and the charging infrastructure during the roll-out process. (Source: TUdelft)

Exhibit 20 presents a standard scenario of EV charging infrastructure development through time. It indicates that in the early stages, charging infrastructure begins to roll out with slow chargers in several locations. At a later stage, the fast-charging stations are added to the charging infrastructure as there is gradual rise in number of EVs. At some point in time, the number of slow chargers is peaked with emergence of fast charging. This is the point when the market gains enough momentum for large-scale EV adoption as there is a vast network of fast and slow charging infrastructure.

Battery Swapping

The time required for charging an EV can be a bottleneck as it takes much longer time and battery swapping has the potential to address this challenge because it takes only a few minutes to swap a battery. This eliminates the need to wait for long hours. A decade ago, battery swapping was recommended as a way of overcoming the challenge around long charging time. Tesla tested it in 2013, demonstrating its ability to swap a Model S battery in 90 seconds, but somehow the idea has not been so successful.

Battery swap is a capital-intensive business, as one has to have additional stacks of batteries. Battery constitutes a significant proportion of a total vehicle’s costs. This means that OEMs have to provide surplus batteries for swapping to work. Tesla experimented this model but figured out that it is a lot cheaper to build a network of superchargers than battery swap stations.

However, in China this idea is gaining a lot of traction and the government is keen on experimenting the battery swap mechanism. Chinese automaker NIO has already completed 500,000 battery swaps. The major challenge with the battery swap is standardization battery itself for a wide range of vehicles and massive repository of additional battery packs.

It would be too early to anticipate as to how the battery swapping would unfold in Pakistan. However, there could be an economic case for battery swap technology for some business models, such as e-rickshaws, as the size of batteries is generally relatively smaller in these variants. Hence, we believe that battery swapping could be a potential solution for three-wheel rickshaws as it would minimize the downtime for commercial deliveries. Yet standardization of batteries would still be major challenge.

Standardization Framework - EV Charging Infrastructure

Standardization provides clarity to manufacturers, ensures compliance with safety standards, and allows for economies of scale. EV charging interoperability means that EV owners can charge their cars at any charging point using their usual choice of authorization and payment method.

Pakistan Standards and Quality Control Authority (PSQCA) is an autonomous body of Government of Pakistan to regulate and enforce quality standards in Pakistan. PSQCA has begun the deliberation and adopted some of the standards for EV charging stations. The list of these standards is provided at Annex-II. Description of IEC standards under consideration by NEECA is provided at Annex-I. Here are some recommendations for standardization based on regional global insights and experiences.

Definition of Charging Station

A public charging station shall have, at least one or more chargers or any combination of the chargers in one or more electric kiosk as listed below:

1. One or more 50 kW DC Fast Charger with CCS-2
2. One or more 50 kW DC Fast Charger CHAdeMO ports
3. One or more Type 2 AC charger with power range 3-22 kW

Minimum of 3 DC fast charger over 100 kW along the motorways/highways every 50 km.

Standardization of Ports

Emphasis on global charging standards to support interoperability between all chargers and all cars is really important.

1. **For AC Charging**, type 2 port could be a prospective standard. Type 2 port supports entire range from slow to fast commercial AC charging up to 43kW. This could be standard for all three, four wheelers and commercial vehicles;
2. **For DC Charging**, CCS 2 connector could be a possible candidate for Pakistan’s standard for DC Fast Charging. CCS 2 could be ideal for Pakistan as it covers all European and Chinese suppliers. Japanese and Korean manufacturers can also supply CCS 2 ports as they have been doing so in the EU. This could be an important step towards standardization the charging infrastructure and addressing interoperability challenges.

Residential Charger – Mode 2 - Type 2 AC Port

1. Charger must employ a dedicated cable of at-least 6 millimeters (mm) from energy meter to charger. Depending on the preference of site owner, EV charger can be installed into an existing meter or new dependent on regulation of the utility;

2. Following protections should be part of charger or added separately via a small distribution board or electric panel; overcurrent, overvoltage, under-voltage, ground fault including DC leakage protection, integrated surge protection.

Commercial Charger Mode 3 – Type 2 AC Port

1. EVSE could be installed into either existing meter or employ a new meter depending on preference of site owner and regulation of utility. It should employ a dedicated cable from meter to the charger;
2. Charger is required to have built-in high efficiency energy meter;
3. Protections should be part of charger or added separately via an electric panel. Protection form overcurrent, overvoltage, under-voltage, ground fault including DC leakage protection, integrated surge protection;
3. Must have a Radio Frequency Identification (RFID) authentication, Bluetooth, 4G and Wifi Based connectivity;
4. Cloud based connectivity to application demonstrating charging status, charge sessions, number of units consumed;
5. Master Application to build a cloud-based network of multiple commercial chargers on Open Charge Point Protocol (OCPP) 1.6 protocol;
6. Built in Load Management via RS 485 connection from external meter to ensure available load capacity is not exceeded.

DC Fast Charger or Mode 4 – CC2 Port or CHAdeMO (50 kW or above)

1. Dedicated transformer from utility;
2. Adequate protection triggers from overcurrent, overvoltage, under-voltage, ground fault including DC leakage protection and surge protection;
3. Charger should have cloud connectivity to remote server and connection to connected services to ensure 24/7 via internet and with ability to resolve issues remotely via Cloud without site intervention;
4. Integrated payment mechanism.

Designation of NEECA as Federal Agency for Oversight and Supervision of EV Charging Infrastructure

- There is a growing concern that in the absence of basic framework for licensing and compliance measures for EV charging standards, it may pose a substantial risk and challenge to this nascent market.
- Therefore, NEECA may be designated as a federal agency for oversight and supervision for EV Charging Installation to ensure that EV charging infrastructure takes place in a sustainable and efficient manner that minimizes costs to the grid, while providing customers with fuel savings relative to conventional fuels.
- NEECA as per its mandate, holds a unique position to ensure that EVs charging infrastructure takes place in a sustainable and efficient manner that minimizes costs to the grid, while providing customers with fuel savings relative to conventional fuels, which helps to drive EV adoption faster.

Technical Compliance of Charger Standards

This step is critical to ensure safe operation of EV Supply Equipment and as well as build the consumer confidence for safe and reliable operation of charging equipment and electric vehicle.

1. Charger should be UL/TUV certified based on 3rd party test and certification. Besides, it is important that 3rd party test and certification must not be self-declared by OEMs.
2. Charger should be protected from overcurrent, overvoltage, under-voltage, ground fault including DC leakage protection, integrated surge protection.
3. Globally EV Supply Equipment are tested according to the following standards and same may be adopted as a national standard:
   a) AC - Type 2 AC System
      I. IEC 61851-1;
      II. IEC 61851-21-2;
      III. IEC 62196-1;
      IV. IEC 62196-2;
      V. IEC 61000;

   b) DC charger
      I. IEC 61851-1;
      II. IEC 61851-21-2;
      III. IEC 61851-23;
      IV. IEC 61851-24;
      V. IEC 62196-1;
      VI. IEC 62196-2;
      VII. IEC 62196-3
      VIII. IEC 61000;

   c) AC Type 2 Portable Mode 2 charger : IEC 62752

Demand Side Planning for Charging Stations

Worldwide, the charging infrastructure presents a “Chicken and Egg” dilemma. On one hand, the investors are reluctant to invest in this new market, and on the other hand, consumers are uncertain to adopt EVs without widespread and reliable charging infrastructure. Hence, success of this transition depends on how quickly the adequate charging infrastructure can be put in place to drive the EV adoption.

One of the most important considerations in setting up a charging station is to ensure that EV chargers are effectively utilized. The utilization of charging station would depend on several factors such as charging behavior, driving pattern, type of housing, proximity of charging station to the commercial markets and the access to the end users. All these factors combined would determine an ideal location of a charging station. However, the key determinants for precise identification and locating a charging network depends on type of charging station and geographical area under consideration.

A study undertaken by SAARC Energy Center suggests that for metropolitan areas, it is advisable to adopt a node-based approach, where the charging demand is usually met at the origin or the destination for intra-city travel. Hence, node-based planning utilizes origination-destination (OD) metric to evaluate charging needs and identify strategic locations to optimize infrastructure requirements emanating from intra-city travel.

Whereas for highways/motorways, one can use a flow or volume-based approach to identify the optimal locations and required number of EV charging stations, which is well suited for station planning at a state level. A recent study conducted by LUMS Energy Institute provides a guideline for placement of DC fast charging stations along the motorways.

Demand-side planning is critical to assess and identify the optimal locations and required number of EV Charging Stations within a geographical area, and key parameters for consideration in the planning process could be:

Parameters	Node-based Approach	Flow-based Approach
Usability	Cities, metropolitan regions	At state level, excluding cities
Charging demand type	Origination-Destination	Top-ups between origination-destination
Major determinants	Number of EVs in the city	Traffic volume passing through the area
Considerations for location planning	Major residential and commercial areas, parking availability	Traffic demand on highways, node spacing in transportation network

Exhibit 21: Modalities of Node and Flow-based Approaches Source: SAARC Energy Center[27]

Assessment of demand charging is critical while planning the charging infrastructure. This needs to take into consideration average distance driven by an EV, average time to recharge, and travel behavior of EV owners, either short intra-city trips or long duration trips.

Governments around the world have used several methods to assess the need for charging infrastructure buildout. There is no simple one-size-fits-all metric that defines the ideal amount of charging infrastructure and it significantly varies from country to country. Exhibit 22 below identifies four of the metrics most frequently used in public charging infrastructure plans.

Metric	Policy example
Absolute Number of Chargers	**Germany:** 1 million public charge points by 2030 **Region of Ile-de-France (France):** 12,000 chargers by 2023
Chargers per square kilometer	**State of Baden-Württemberg (Germany):** Minimum public charger coverage of one 20 kW charger in every 10x10 km grid and one 55 kW charger in every 20x20 km grid
Chargers per kilometer of road	**United Kingdom:** 95% of motorways and A-roads should be within 20 miles of a charger
Electric vehicles per charger	**France:** One charging station for every 10 electric vehicles

Exhibit 22: Typical metrics for evaluating public charging infrastructure and policy examples.[28]

The National EV Policy provides recommendation to have at least one DC fast charger to be installed in every 3x3 km area. The policy also calls for installation of DC fast chargers along motorways and highways after every 15-30 km. This method or metric can be useful for ensuring access or to provide effective geographic coverage. This metric does not account for actual traffic flow or volumes and it works best when the EV market is adequately developed.

[27] **SAARC Energy Center**, "Action Plan for Electric Utility Companies for EV Charging Infrastructur" (2019).
[28] **Dale Hall and Nic Lutsey**, International Council on Clean Transportation (ICCT), "Charging infrastructure in cities: Metrics for evaluating future needs" (2020) https://theicct.org/sites/default/files/publications/EV-charging-metrics-aug2020.pdf

Coverage based planning may not be an effective strategy for Pakistan as it may lead to underutilization of charging infrastructure especially in the early stages with low EV penetration. However, it may be more logical to use the EV per Charger metric to assess and continue to increase the number of chargers as per the actual stock of vehicles in that geographic location under consideration. This would ensure that charging infrastructure follows the demand curve to achieve an optimum utilization of charging assets.

Chapter – IV: Assessing the impact of Electric Mobility on the Grid & Distribution Network

Traditionally, the road transport sector in Pakistan has been primarily driven by petroleum fuels with no reliance on power sector. However, this is going to change as electricity is poised to become the dominant fuel in the road transportation sector in the coming years. Today, electric mobility is at the crossroads, and, shifting reliance of road transport from petroleum to electricity will potentially disrupt major supply chain of automotive, power and petroleum industries in the country.

Charging infrastructure integrates mobility with power sector and has the potential to disrupt both the transport sector and electricity distribution. Thus, power distribution companies have a tremendous role to play for uptake of electric mobility in Pakistan. With the projected increase in electric vehicles in the coming years, it is extremely vital for the power planners, grid and distribution operators to understand the potential impact of EVs on national grid. Scaling up EV adoption requires significant support from power generation and distribution sectors along with regulatory, policy and fiscal incentives to create an enabling charging ecosystem while maintaining reliability of the grid.

As EV adoption is expected to grow, power Distribution Companies (DISCOs) and power generators would have to be prepared for additional supply of electricity and make investments into the distribution network upgrades to meet the charging infrastructure needs. During this transition towards electric mobility, DISCOS would have to play a leading role in connecting vehicle charging stations to the grid network. Hence, it is critical for DISCOS to strengthen their capabilities to operate, maintain and support the charging infrastructure network in the country.

The primary impact of EVs on the electricity network is associated due to its inherent attributes such as unpredictable and mobile load. Therefore, it becomes a challenge for DISCOs to forecast when—and where—that electricity will be needed. With considerable growth of electrical vehicles in the near future, DISCOS need to address this challenge and maintain reliability of the grid.

Worldwide experience suggests that the projected growth of electric vehicles will not drive substantial increase in total electricity demand. Thus, in relative terms, the additional need for power generation capacity for electrified transportation would not be enormous in comparison to total electricity demand. For example, projected EV growth in Germany would only add about 1 percent to the total electricity demand at 5 gigawatts (GW) of generation capacity by 2030.[29] Likewise for the U.S., S&P Platts analytics outlook data suggests that total electricity demand for EVs would reach 44 terawatt-hours (TWh) in 2030[30] which is about less than 1% of total electricity demand.[31] Our modeled

[29] **Mckinsey & Company**, "The potential impact of electric vehicles on global energy systems" (2018) https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-potential-impact-of-electric-vehicles-on-global-energy-systems

[30] **S&P Global**, "US EV sales tumble in 2020, but EV load increases with more charging stations" (2020) https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/012821-us-ev-sales-tumble-in-2020-but-ev-load-increases-with-more-charging-stations

[31] **U.S. EIA** "EIA's Annual Energy Outlook 2020 projects consumption growing more slowly than production" (2020) https://www.eia.gov/todayinenergy/detail.php?id=42635

projections for EV penetration in Pakistan also point to similar estimate of additional 2% electricity load which translates into additional power capacity of 1.5-2 GW.

Although, the impact of high penetration of EVs on distribution network would be marginal, it will require a significant upgradation in distribution network to handle the power load at certain locations and time periods of high charging demand. While the EVs are unlikely to add any significant strain on the power grid at a national level, it will likely reshape the power load curve at the distribution scale. The major impact on the distribution network will be an increase in evening peak loads, as people would plug in their EVs when they return home from work. At a national level, this would represent a small load, which the power network could likely absorb without any challenge. However, at a distribution scale, this changing load curve may lead to electricity network congestion or voltages below normal.

In addition to exerting further load on the system, EVs could also add flexibility and offer grid-stabilization services. With bidirectional electrical flows, EVs could serve as moveable energy storage devices, which means EVs could store electricity at off-peak hours and feed them back to the grid at peak hours. This functionality is characterized as Vehicle2Grid (V2G) which allow electricity to flow both ways. Although V2G capability of EVs is still being experimented at pilot scale, industry experts believe the technology has the potential to be viable for real-world applications.

Existing Power Generation and Supply Capacity and Demand Projections

Pakistan continues to face the challenge of being unable to adequately balance the supply and demand of electricity. The country in general has been through many cycles of power booms and then busts crisis. During 2005 and 2017, Pakistan experienced an acute electric power shortage. During this period, economy suffered due to countrywide blackouts for much of the day. Around 2015, Pakistan began to accelerate the power capacity additions with help of Chinese investments. Today, we have reached a point where the installed power generation capacity is significantly greater than the actual demand.[32]

Currently, power supply capacity has flipped to a surplus crisis with addition of over 13,298 MW capacity in the last few years. As of 2020, the total installed capacity in the country stands at 38,719 MW[33]. However, the grid capacity at which the transmission and distribution network can deliver the power has not kept its pace with new generating power capacity. This has led to a crisis where we have ample power generation capacity but that cannot be exported to due to underdeveloped transmission and grid infrastructure. The maximum demand in summer peaks around 25,000 MW. Despite this overcapacity, Pakistan still has power shortages because of the underdeveloped grid capacity. Another challenge is the considerable variation between the peak demand during winter and summer. Peak summer demand exceeds 25,000 MW and while in the winter, it is around 15,000 MW.

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[32] **Reuters**, Pakistan faces an unexpected dilemma: too much electricity (2021) https://www.reuters.com/article/us-pakistan-energy-climate-change-featur-idUSKBN2AO27C
[33] NEPRA State of Industry Report 2020

The surplus capacity has been further aggravated due to low demand in the wake of current account deficit crisis, rupee depreciation and now the COVID-19 pandemic. The surplus capacity poses as an extreme challenge for the government as it has signed the power purchase agreements based on take-or-pay contracts. That means that government has to pay power producers capacity payments even when there is no demand and power plants do not generate any electricity.

Now the government has no other feasible option other than delaying some of the planned capacity addition projects, as there will not be enough demand in the coming years. This makes a compelling case for higher market adoption of electric vehicles in Pakistan, as they would induce additional electricity demand and utilize the excess generation capacity, and at the same time it would mitigate the GHG emissions in the cities.

With regards to future electricity demand, National Transmission and Dispatch Company (NTDC) has developed an Indicative Generation Capacity Expansion Plan (IGCEP) with modeled scenarios of power demand up to 2047.[34] IGCEP has modeled projections based on three economic growth scenarios; low (4.5%), normal (5.5%) and high (6.5%) growth rates of GDP. Even if we consider the low growth scenarios and continued economic slowdown due to the pandemic, IGCEP projects the peak electricity demand in 2030 around 44,958 MW. Pakistan also plans to increase the share of wind and solar to 30%, while another 30% will be generated from river-run dams.[35]

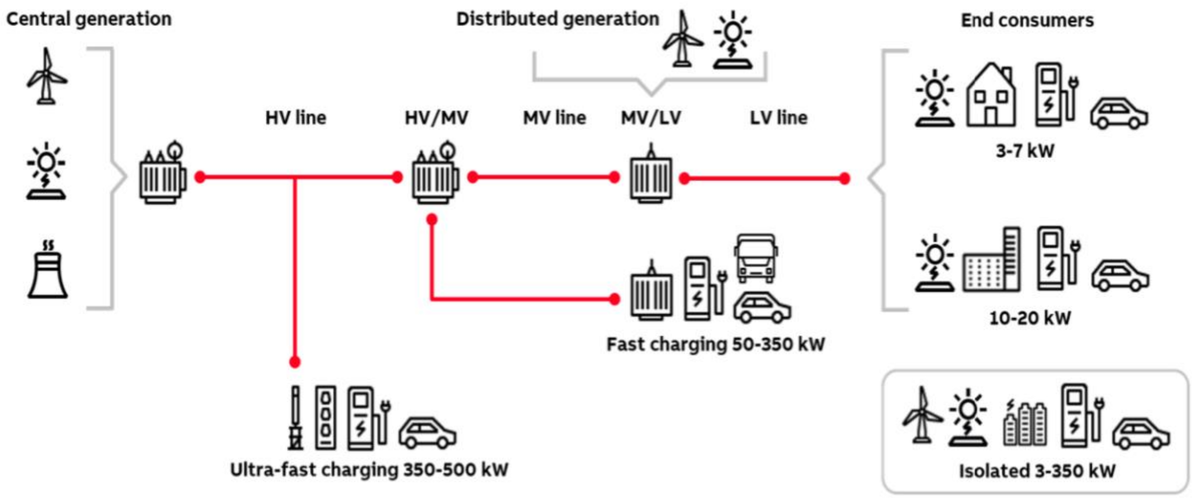

Exhibit 23: Schematics of interconnection of EV charging station with grid network[36]

The Exhibit 23 represents how electricity is delivered from power generation to the end consumer or in this case the EV charging stations. Power plants generate electricity at 11 kV and the voltage is stepped up, and transmitted via primary transmission lines or Ultra High Voltage (UHV) lines which

[34] **National Transmission and Dispatch Company (NTDC)**, "Indicative Generation Capacity Expansion Plan (IGCEP)" (2019)
https://nepra.org.pk/Admission%20Notices/2019/09-September/IGCEP%20Plan%20(2018-40).pdf
[35] **World Bank**, "Expanding Renewable Energy in Pakistan's Electricity Mix" (2020)
https://www.worldbank.org/en/news/feature/2020/11/09/a-renewable-energy-future-for-pakistans-power-system
[36] **ABB** "Exploring the impacts of E-Mobility on the power grid" (2020)
https://library.e.abb.com/public/c06c7e5334b04d5cb2a3ebaf60b5354d/PowerConsultingE-MobilityBrochure.pdf?x-sign=2qndY1RAZh8pGQtCWJ9sxqbyPhVeqpLK7ELAg8FNNAXNAZ3BFoI2ueBmqayvFCDw

usually operate at 500/220 kV. The primary transmission lines bring power over long distances to substations near a population center to step down the voltage to serve the power demand. In these substations, the voltage is converted to 132 kV and then transmitted via secondary transmission lines or High Voltage (HV) lines to 132 kV substations.

From these 132 kV substations, the power is again stepped down to deliver at a Medium Voltage (MV) at 11 kV to distribution transformers, which further steps down to Low Voltage (LV) to 220 V for connecting EV chargers. The AC current is then converted to DC in the fast charger to match the battery voltage of the vehicle. The schematics demonstrates that depending on the power capacity and application of the charging stations, they can directly be connected to HV, MV or LV lines.

As illustrated in the diagram, an ultra-fast charger power can deliver very high amounts of power with capacity range between 350-500 kW and they can be directly be connected to HV lines. As the name suggests, these ultra-fast chargers can charge EVs in fairly short period of time typically under 15-20 minutes. Typically, these chargers are well suited to motorways/highways, as the stopover time at these routes is usually very short.

Modeling the Impact of Electric Mobility on National Grid

To investigate the possible impact of electric mobility on the national grid, we developed a model to compute projected increase in electricity demand and the net impact on energy value chain and GHG emissions.

The model uses top down estimates and projects scenarios based on three vehicular growth forecasts. The model takes into consideration various types of vehicles i.e. two-wheelers or motorbikes, three-wheelers or rickshaws, cars or SUVs, buses and trucks. It takes market-based estimates of annual distance travelled by type of vehicle and associated consumption of fuel in liter/km for Internal Combustion Engine (ICE) vehicle and kWh/km for an electric vehicle.

The model employs historical vehicular growth data from Statistical Appendix on Transport and Communication of Pakistan Economic Survey reported during 2006-2019 period.

Key Model Assumptions

The first input for our model is the EV penetration rate through 2030 that we assumed. Based on these assumptions, we computed the annual sales number of EVs on the road and then projected electricity demand for charging EVs. These projections drove our estimates of both EV-related generation and fuel savings.

The model employs EV penetration targets as percentage of new vehicles added based on three distinct cases; low or conservative, moderate and the high or aggressive market growth. It provides an assessment of expected EV penetration in Pakistan to the year 2030, with three adoption pathways.

High or aggressive EV penetration scenario: This case represents a rapid adoption of EVs due to significant decline in battery prices worldwide. Under this case, EVs are likely to achieve a price parity with conventional ICE vehicles in the medium term by 2025. This is in line with the forecast by the Bloomberg New Energy Finance (BNEF) that suggest Li-ion battery prices are expected to come down to US$100/kWh in 2024.[37]

The price point of US$100/kWh is being considered as a tipping point in the electric mobility sector, where consumers will no longer regard electric vehicles as costlier options. Under such conditions, adoption would be much quicker and increasing number of consumers are likely to switch to EVs due to favorable economics.

If purchase cost of EV and ICE is assumed to be the same, then car buyer would be more than willing to buy an EV over ICE because purchase cost being the same, EVs would offer much higher cost savings in terms of lower running and operational expenses. Hence, we believe under this scenario, it is reasonable to assume that we might be able achieve this high penetration scenario if lithium-ion battery prices come down to US$100/kWh.

Moderate EV penetration scenario: This case represents that EV penetration is based on the market conditions where prices of Li-ion batteries are still high and we reach US$100/kWh mark towards the end of this decade. Under this scenario, local automotive market would be likely to adopt slower transition compared to aggressive scenario. The model assumes that EVs would have achieved 30% of market share by the end of 2030. We assume that medium EV penetration scenario is consistent with the target set forth under the NEVP and EVs are like to penetrate as 30% of sales by 2030 presented in the Exhibit 24 below.

Low EV penetration scenario: It presents a business as usual scenario and assumes the advancement in EV technology takes place at much slower pace and globally cost of EVs stays much higher than previous two cases. Eventually it builds upon the case that we do not achieve required gradual localization of EV manufacturing. Subsequently, EV penetration remains quite low. In this case, EV penetration is assumed to increase linearly from 0.1% in 2021 to 6% in 2025 with maximum EV penetration of 15% by 2030. These three market growth scenarios of EVs are estimated as percentages of new vehicle sales projected from the year 2021 to 2030 as illustrated in Exhibit 24 below:

	2021	**2025**	**2030**
High EV penetration	1.00%	25%	50%
Moderate EV Penetration	0.50%	14%	30%
Low EV Penetration Target	0.10%	6%	15%

Exhibit 24: EV penetration growth assumptions as percentage of new sales

[37] **S&P Global Market Intelligence** – As battery costs plummet, lithium-ion innovation hits limits (2020) https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/as-battery-costs-plummet-lithium-ion-innovation-hits-limits-experts-say-58613238

Fuel Mix Considerations for ICE and EVs

Based on the consultations with a number of auto manufacturers, including Jolta Electric, Sunra Electric, Sazgar Autos, MG Motors, Audi and the Planning Commission, we gathered the estimates for annual distance travelled and fuel mix for various types of vehicles as presented in the Exhibit 25 below. The assumptions are based on actual market trends which indicate that motorbike or two wheelers and three-wheeler/rickshaws mainly use petrol, whereas, cars, Light Transport Vehicles (LTVs) and Sport Utility Vehicles (SUVs) predominantly use petrol with a small fraction of diesel or Compressed Natural Gas (CNG).

Vehicle Type	Average Vehicle Consumption			
	Average Annual Distance	Electricity	Petrol	Diesel
	km	km/kWh	km/liter	km/liter
2 W Motorbikes	14,600	40	40	–
3 W Autorickshaw	45,000	20	20	–
4W Sedan, SUVs LDV	12,000	6	11	17
Buses	75,000	1.3	3	4
Trucks	75,000	1	2.5	3.2

Exhibit 25: Model assumption for average annual distance travelled and fuel consumption efficiencies by vehicular type. Source: Market Surveys, author's own estimates and USAID IEP Planning Commission, Pakistan

Electric Vehicles Adoption Scenarios

The forecasts for EV adoption are critical for policy-makers for right-sizing public charging infrastructure, to estimate the need for investments to meet additional electricity and to recognize the potential climate benefits with increased deployment of EVs.

	High EV Penetration		Medium EV Penetration		Low EV Penetration	
Vehicle Segment	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**
Two-wheelers	620,944	1,439,689	337,794	863,814	150,269	431,907
Three-wheelers	21,539	49,939	11,717	29,963	5,212	14,982
Cars/LDVs	88,409	225,670	48,095	135,402	21,395	67,701
Buses	1,335	3,094	726	1,857	323	928
Trucks	875	2,028	476	1,217	212	608
Total	733,102	1,720,420	398,807	1,032,252	177,411	516,126

Exhibit 26: EV penetration (as percentage of new sales)

Based on the inputs to the model, we project annual EV penetration to demonstrate a range of possible EV sales outcomes by 2030. Exhibit 27 shows the potential deployment of electric vehicles both annual and cumulative sales of new electric vehicles through 2030. Under high or aggressive EV penetration scenario which is consistent with NEVP; cumulative EV population is linearly projected to increase from 25,000 units in 2021 to 8.2 million EVs over the course of next ten years by 2030.

In the long term, as EVs reach cost parity with ICE vehicles sometime after 2025, we expect sales volumes to increase significantly especially for two and three wheelers. As shown, the annual electric vehicle sales increase from about 0.7 million in 2025 to over 1.7 million in 2030. Whereas, in the medium and low EV market penetration scenarios, results show a cumulative deployment of EV of about 4.8 million and 2.2 million units by 2030, respectively. In all these three cases, motorbikes or two-wheels constitute the biggest share with over 84% followed by cars (12%), three-wheelers (3%), buses (0.17%) and trucks (0.14%).

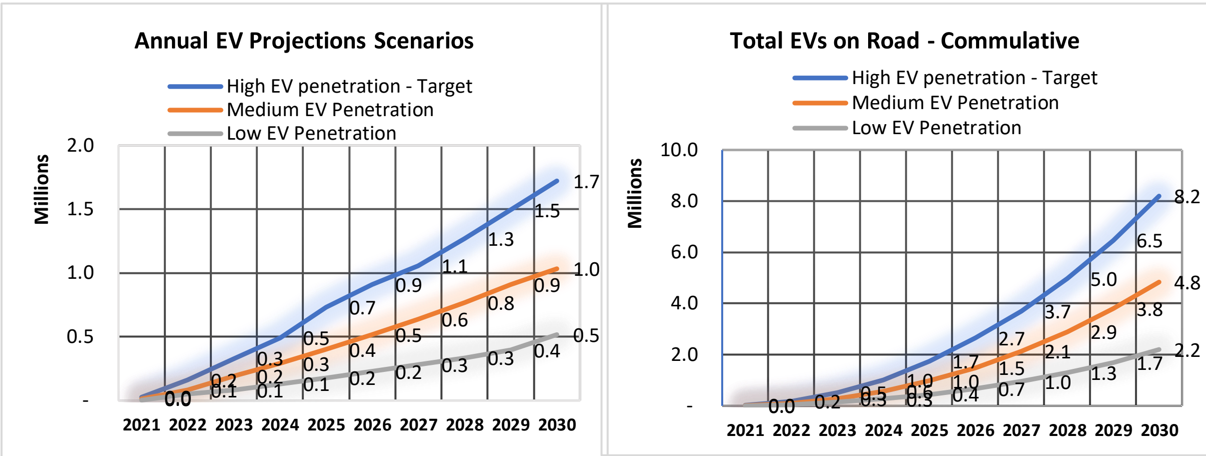

Exhibit 27: Annual EV projections (left) and the total or commutative EVs on the road (right)

Electricity Demand associated with increase in EV sales

Next, the model computes the additional electricity demand in gigawatt hours (GWh) due to increase in EV population using equation 2 below for high, medium and low EV penetration scenarios. Exhibit 28 shows that even in the high market growth case with cumulative addition of over 8.2 million EVs by 2030, demand for electricity hovers around 7,200 GWh. For comparison, the 7200 GWh translates into 5% of the total electricity generation of Pakistan during last fiscal year in 2020 which stood at 134,745 GWh.[38]

$$\textit{Fuel Consumed by ICE vehicles} = No.of\ ICE\ Vehicles \times\ Fuel\ Consumption\ \left(\frac{Litres}{km}\right) \times Total\ Distance\ Travelled\ (km)$$

Equation 1

$$\textit{Electricity Consumed by EVs} = No\ of\ EVs\ \times Electricity\ Consumption\ \left(\frac{kWh}{km}\right) \times\ Total\ distance\ travlled\ (km)$$

Equation 2

Hence, high market EV deployment is not likely to be a major challenge for electricity grid network in Pakistan. Although we could see power spikes in some areas with high saturation of charging station

[38] NEPRA State of Industry Report 2020 https://www.nepra.org.pk/publications/State%20of%20Industry%20Reports.php

in certain locations with limited grid capabilities. To address this challenge, distribution companies would need to anticipate demand for EVs and invest into network expansion and strengthening to facilitate high uptake of EV charging infrastructure.

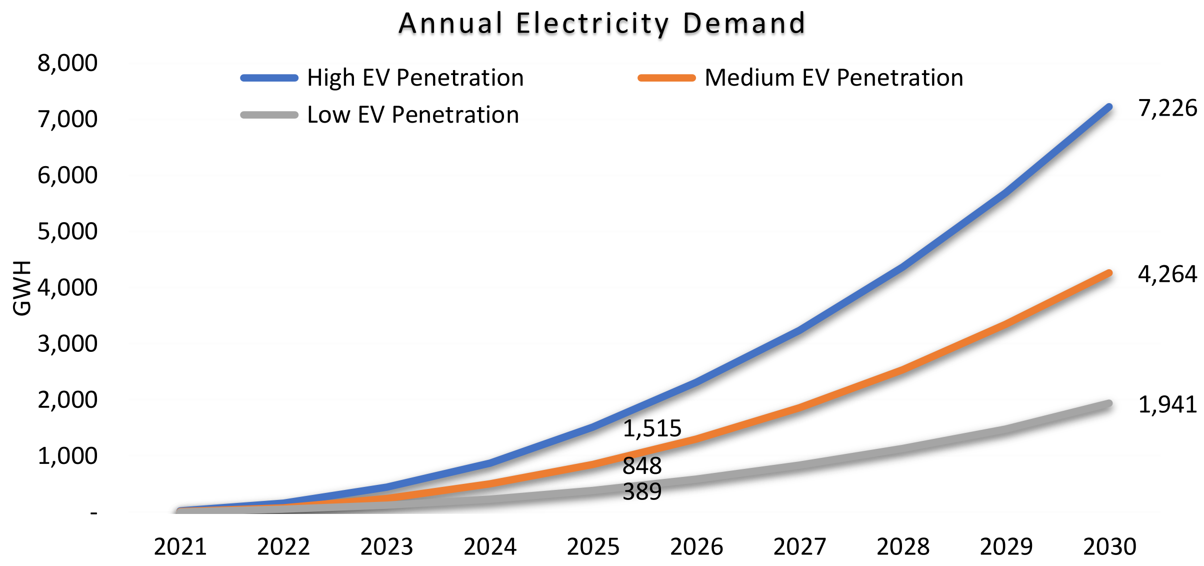

Exhibit 28: EV induced annual electricity demand in GWh

Hence, our model demonstrated that high EV penetration is not likely to cause large increases in power demand through 2030; instead, it potentially adds about 2 percent to the total and requires about extra 1.7-2 gigawatts (GW) of generation capacity by 2030. As per the new renewable energy policy 2020, the Government aims to increase the share of renewables to 30% by 2030 from about 3% today. Hence, almost all this additional capacity could be met through renewables, including wind and solar power, with some gas-powered generation by the end of this decade.

Potential Fuel Savings

EVs use about 30% of the energy of ICE vehicles, offers substantial economic and financial savings and reduces reliance on energy imports[39]. Each EV added on the road displaces an ICE vehicle, and hence provides an opportunity for fuel reduction over useful lifetime. The model computes the fuel savings in Million Tonnes of Oil Equivalent (MTOE) as a result of increase in electric fleet. Thus, on the basis of projected sales of EVs, fuel reduction for petrol and diesel is determined based on the conversion efficiencies of ICE vehicle types.

Exhibit 29 illustrates the fuel saving during the period 2021-2030 based on three distinct cases. With the best-case scenario, high EV penetration in the market would offer a fuel reduction of over 18 MTOE during the period 2021-2030. Likewise, in a medium EV penetration case, potential reduction in fuel consumption is computed to be about 10 MTOE and, in the low growth scenario, it is estimated to about 5 MTOE. For a reference, it could be useful to highlight that in 2020 Pakistan's total final energy consumption reported was 54.9 MTOE and the transport sector alone consumed 17.07 MTOE amount of energy during the same period.[40]

[39] All Electric Vehicles: US Department of Energy: https://www.fueleconomy.gov/feg/evtech.shtml

[40] Pakistan Energy Year Book 2019-20

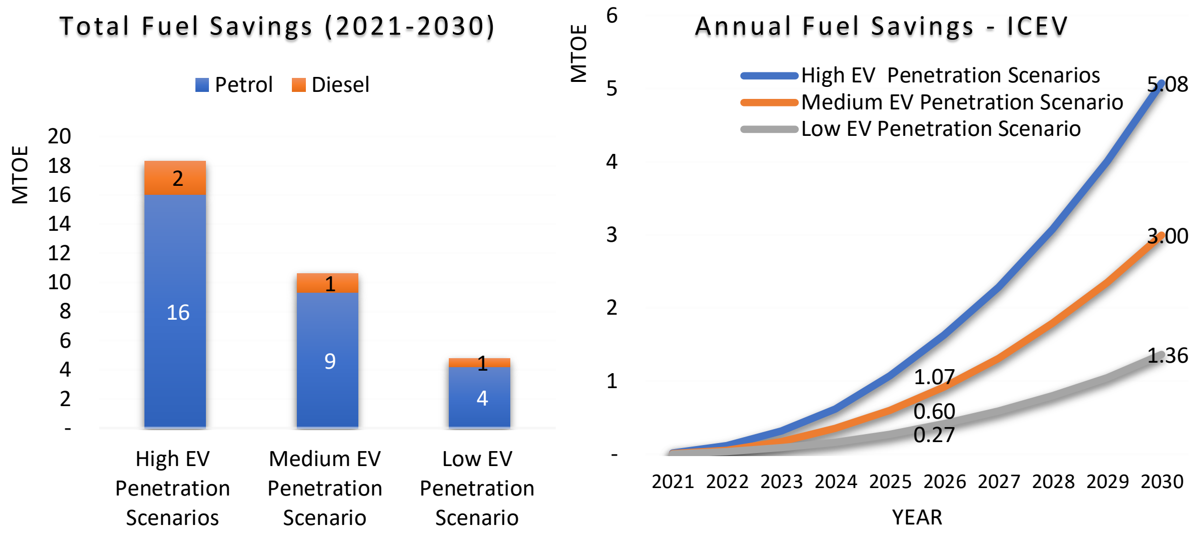

Exhibit 29: Commutative EVs on the road 2021-2030 (left) and annual EV sales projection (right)

EVs Would Add to the Peak Loads at Distribution Levels

Adoption of EVs will grow in concentrated groups, as consumers tend to get influenced by EV purchases in their vicinity. While the uptake in EV sales is unlikely to cause a significant increase in total power demand, it would reshape the electricity load curve. The significant impact will be on an increase in evening peak loads, as people plug in their EVs when they return home from work. Although, at a national level, this effect will represent a relatively small percentage at most. However, at a distribution level, this changing load curve may lead to electricity network congestion or voltages below normal.

Hence, for DISCOS, it would be important to identify the hot spots and concentration points of EV, such as public EV-fast-charging stations and commercial-vehicle depots, as there we are likely to see significant increases in local peak loads. Commercial EV charging loads could also rise gradually as public charging infrastructure becomes widely available. However, at the residential areas the load growth may not be as noticeable, as the aggregation across many households would reduce the relative increase in peak load at a substation level.

A simulation study undertaken by Forum of Regulators assessed the impact of high EV penetration on distribution grid network.[41] The study found out that slow chargers (less than 2 kW capacity) do not have any adverse impact on any of the distribution feeders at residential areas. However, DC fast charging can cause significant rise in peak loads and drop in voltage levels, particularly in the case when baseline load of transformers is already over 90% for both commercial and residential feeders. The simulation concluded that for transformers with less than 50% baseline load, rise in 20% of EV

[41] **Forum of Regulators**, "Study on Impact Of Electric Vehicles on the Grid" (2017) http://www.forumofregulators.gov.in/Data/study/EV.pdf

load will not lead to voltage deviations beyond allowable limits. However, for transformer loadings beyond 90%, occurrences of transient fluctuations could rise significantly.

Potential Solutions to Mitigate the Grid Impacts

The primary impact of EVs on the electricity network is due to its inherent attributes such as unpredictable and mobile load. This uncertainty makes it difficult to accurately measure the impact on the local distribution network. Energy players and distribution companies have several ways to address this situation. To minimize the costs to EV owners, while maintaining the reliability of the grid for EVs, DISCOS need to act in three main areas:

DISCOs Need to Plan Ahead

The power distribution companies will have to make adequate plans and intervention to address challenges emanating from EV charging stations. Therefore, DISCOs should build a roadmap of programs that will enable them to enhance the grid to meet EV demand at a reasonable cost. To efficiently manage this power demand, DISCOs should utilize their network maps to identify the sites where they anticipate demand for EV charging infrastructure. The DISCOs need to take into consideration the optimal number of charging stations that can be installed and managed without compromising on network reliability.

Potential sites for charging stations could be classified into those that would require negligible or no upgrades and those that would need extensive grid upgrades. Based on these insights, DISCOs could identify distribution infrastructure, including 132 kV substations, 11kV feeders and distribution transformers which are not overloaded and have sufficient power capacity available for delivery to charging stations. Feeders that have tendencies of high transformer loadings need to be upgraded. It may also be feasible to shift some load from overloaded substations or transformers to other underutilized stations to reduce the strain on the grid.

The high concentration of EVs in certain locations could cause outages from overloading of the distribution transformers. In the event of any such outages, it will degrade the power quality in other connected feeders and may cause intermittent voltage fluctuations. Therefore, in order to manage the EV load on a network, the DISCOs should establish a monitoring mechanism for distribution transformers to forecast the EV peak loads.

Majority of distribution transformers with power rating of 100-200 kVA will serve majority of the EV charging stations. In commercial areas or work spaces, adding several Level 2 chargers (3kW -22kW) along with the current usage would add significant stress on the transformer. Hence, a major upgrade could be required in areas of higher adoption to meet the demand of EVs in commercial feeders. For DC fast charging stations, separate transformers are required to be installed and this would add to the expenditure of setting up EV infrastructure in Pakistan.

Optimal placing of charging stations is the key to drive EV adoption. To achieve this, DISCOs would be required to prepare and make a series of regulatory interventions that will allow them to recoup their investments in upgrading distribution system.

Each distribution company in Pakistan could set up a technical oversight committee to review the grid and network upgrades and subsequently grant permits for setting up of EV charging stations. The location of the charging stations would have to be identified jointly by relevant DISCO, city or local administration and/or transport agency, such as National Highway Authority (NHA) for charging stations along the motorways/highways.

Influence Customers' Charging Behavior

EV charging would likely reshape the electricity load curve and it will coincide with existing peak loads. This can be mitigated by influencing the charging behavior and incentivize EV owners through Time-of-Use (ToU) electricity tariffs to encourage them to charge after midnight instead in the early evening. The charging tariffs should be designed in a way that it would discourage customers from charging at times of high demand. A study undertaken by Mckinsey & Company demonstrates that Time-of-Use tariffs can reduce the peak load almost by half. However, ToU could present another challenge especially in the case of high EV penetration that a large number of EV drivers could respond to the price signals and move to off-peak after the midnight.

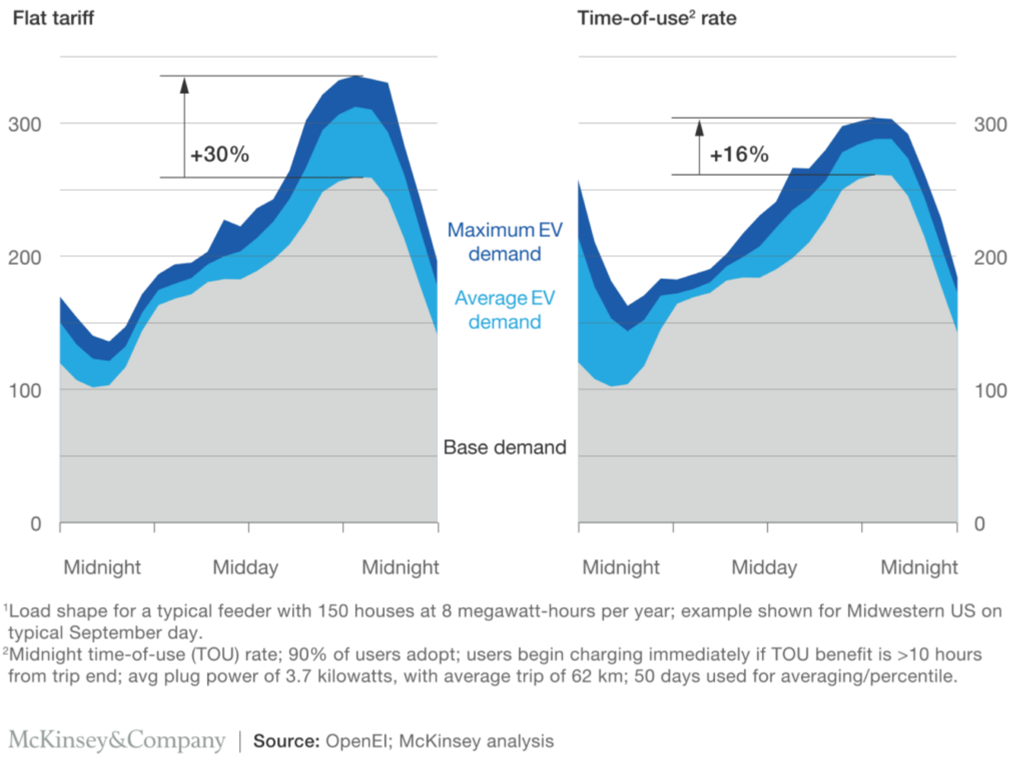

Exhibit 30: Flat Tariffs vs Time-of-Use tariffs[42]

As illustrated in Exhibit 30, ToU rates greatly influence the charging patterns. If the overwhelming majority of EV owners are encouraged to charge at off-peak hours, it will eliminate the need for investments in higher-voltage and more-expensive transmission circuits and substations.

[42] **Mckinsey & Company**, "The potential impact of electric vehicles on global energy systems" (2018) https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-potential-impact-of-electric-vehicles-on-global-energy-systems

On the distribution scale, off-peak charging would limit the number of substations that would otherwise need some upgradation as well as eliminate the need for installation of new capacity of circuits, switches, and distribution transformers.[43] It can minimize the overall need for new power generation investment. Hence, ToU pricing can be an effective strategy to reduce the unit cost of electricity by incentivizing the EV owners to adopt optimized charging behaviors.

Leverage New Technologies

Smart Charging

Power distribution companies can employ emerging technologies to limit the strain that EVs can put on the grid and manage the grid upgrade costs. Investments in infrastructure improvements such as advanced electricity metering technology or smart charging can help reduce the strain on the grid. With this technique, charging takes place following the load demand curve and, hence, EVs are charged at low demand hours.

Smart charging technology requires the installation of an intelligent vehicle controller that is coordinated with smart controllers installed on production side and both sides communicate optimized EV charging. The lower the power demand, the faster rate of EV charging. Although smart charging technology is a fairly advanced concept for Pakistan, the DISCOS must work towards implementing managed charging to ensure that the grid network does not get overloaded.

Deploy Energy Storage

By installing energy-storage units at the charging stations, one can attain multiple cost and technological benefits. With these storage units, energy can be stored during times of low demand and then discharged at times of peak demand, thus reducing the peak load.[44] Energy storage services could enhance the charging capacity of electric vehicles stations through:

- **Grid reinforcement** by limiting the installations of new lines or reinforcement of existing lines
- Manage **peak shaving** by reducing the energy costs by flattening the power demand peaks
- Offer **grid flexibility** services by utilizing complementary revenues with grid stabilization services
- Maximize **self-consumption** of onsite renewable production

Hence, primary benefits of employing energy storage include shaving peak loads to reduce demand charges and avoid grid upgrades as well as taking advantage of lower power prices during lower demand. As the cost of batteries continues to decline, using energy storage to level out the load profiles will become more attractive.

Vehicle to Grid (V2G)

It is one of the most advanced methods of smart charging, by which energy stored in EV batteries is discharged back to the grid. V2G involves bidirectional charging which can help EV owners to charge

[43] **Boston Consulting Group**, "The Costs of Revving Up the Grid for Electric Vehicles" (2019) https://www.bcg.com/publications/2019/costs-revving-up-the-grid-for-electric-vehicles
[44] **SOCOMEC**, "Energy Storage for Electric Vehicle Charging Infrastructures applications" (2020) https://www.socomec.com/energy-storage-electric-vehicle-charging-infrastructures_en.html

their vehicles when power is the cheapest and discharge during peak load demand. V2G capability of EVs is still being experimented at pilot scale, but industry experts believe that technology could become viable for real-world applications.[45] V2G can improve asset utilization, and increasing reliability and resiliency of network parameters, such as voltage control and frequency regulation.

With V2G application, EVs could also augment the grid in managing the decentralized, fluctuating power output from renewables. For instance, it is difficult to control the power output from solar and wind, and hence, they require more flexible resources to keep the power balance in the electrical grid.[46] Therefore, EVs could also provide short-term storage to compensate for daily fluctuations induced by intermittent renewable sources.

[45] **Electronic Design**, "A Big Bet on Bidirectional EV Charging" (2020) https://www.electronicdesign.com/markets/automotive/article/21134047/a-big-bet-on-bidirectional-ev-charging

[46] **World Economic Forum**, "How will electric cars affect the energy grid?" (2015) https://www.weforum.org/agenda/2015/02/how-will-electric-cars-affect-the-energy-grid/

Chapter – V: Modeling the Impact of Electric Mobility on GHG Emissions in Pakistan

ICE vehicles produce direct emissions through the tailpipe by burning fuel to power an engine. Conversely, EVs produce zero direct emissions. In general, vehicle emissions can be classified into two groups: air pollutants, which contribute to smog, and haze; and greenhouse gases (GHGs), such as carbon dioxide and methane. When measuring the GHG emissions in road transport, one must consider emissions in terms of:

1. Tank-to-wheel (TW) emissions related to the direct emissions when a vehicle is running
2. Well-to-Tank (WT) emissions associated with the extraction, refining and transportation of the fuel or production of electricity, and
3. Emissions as a result of manufacturing during the production of a vehicle.

One of the ways to compare the GHG emission of ICEs and EVs is using Life Cycle Assessment (LCA). LCA measures the overall environmental impact during complete life cycle of a vehicle, from manufacturing to driving and eventually recycling of the vehicle.

From an LCA standpoint, the total CO2 emissions of an EV over its full life cycle vary significantly depending on the sources of power used where the vehicle is manufactured and driven. For example, in countries where clean energy sources such as nuclear power and renewables are predominant, EVs would compare favorably with ICE if total CO2 emissions are measured. However, in carbon intensive markets, where fossil fuels such as crude oil and coal are the main sources of energy, EVs would be less attractive in terms of GHG emission mitigation potential.

ICE vehicles burn hydrocarbon fuels derived from fossil energy sources. Most of the GHG emissions coming from conventional vehicles are emitted through tailpipe. We calculate the main GHG emission for ICE vehicles which are the Carbon Dioxide (CO2), Methane CH4 and nitrous oxide N2O for both petrol and diesel. In the absence of localized fuel emission factors for Pakistan, we use the reference emission factors published by the U.S. Environmental Protection Agency as provided in the Exhibit 31 below.

Emission Factors	kgCO2/litre	CH4 g/litre	N2O g/litre
Petrol	2.29	0.100385427	0.021133774
Diesel	2.66	0.108310593	0.005283444

Exhibit 31: Fuel emission factors for petrol and diesel Source: US EPA[47] *emission factors converted to litre from gallons.*

Generally, GHG emissions are measured in carbon dioxide equivalent or CO2 equivalent, abbreviated as CO2-eq. CO2 equivalent is a metric used to compare the emissions from various GHGs, such as methane or nitrous oxide on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming

[47] US EPA Emission Factors (2014): https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

potential.[48] Carbon dioxide equivalents are commonly expressed as million metric tonnes of carbon dioxide equivalents, abbreviated as MTCO2-eq.

Global Warming Potential (GWP)	
CH4	25
N2O	298

Exhibit 32: Global Warming Potential for methane and nitrous oxide, Source US EPA.

The carbon dioxide equivalent for a gas is derived by multiplying the amount of the gas by the associated GWP. For example, the GWP for methane is 25 and for nitrous oxide 298. This means that emissions of 1 metric tonnes of methane and nitrous oxide respectively is equivalent to emissions of 25 and 298 metric tonnes of CO2.[49] The total GHG CO2 equivalent emission are product of fuel consumption by ICE vehicles and associated GWP factor. Correspondingly, once we have calculated the total CH4 and N2O emissions on the basis of fuel consumption in liters, they are multiplied with GWP factors to determine the carbon dioxide equivalent in MTCO2-eq.

General Equation for GHG Emissions

Current methods of measuring GHG emissions focus on CO2 emissions on tank to wheel basis when a vehicle is running. For the purpose of determining the net impact of GHG emissions of an EV versus an ICE vehicle in Pakistan, our emphasis is on the tank to wheel (TW) emissions. For TW measurement of EV, the total CO2 emissions will have to be assessed from the charging the battery through national electricity mix.

For measuring GHG emission of an ICE vehicles when fuel is used

$$\boldsymbol{ICE\ GHG\ Emission} = No.of\ ICE\ Vehicles \times\ Fuel\ Consumption\ \left(\frac{Litres}{km}\right) \times Fuel\ Emission\ Factor\ \left(\frac{tCO2eq}{litre}\right)$$

Equation 1

For measuring GHG emission of an EV vehicles when electricity is used

$$\boldsymbol{EV\ GHG\ Emission} = No\ of\ EVs\ \times Electricity\ Consumption\ \left(\frac{kWh}{km}\right) \times\ Grid\ Emission\ Factor\ (\frac{tCO2eq}{kWh})$$

Equation 2

The grid emission factor is defined as an average emission rate of a given GHG for a given source, relative to units of activity. It is usually stated as GHG emission rate per unit of input or per unit of output.

$$\boldsymbol{Net\ GHG\ Emission\ Reduction}\ (\boldsymbol{tCO2eq}) = ICE\ GHG\ Emission\ - EV\ GHG\ emission$$

Equation 3

[48] GHG Emission – CO2 equivalent: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Carbon_dioxide_equivalent
[49] CO2 Equivalents - Climate Change Connections, access: https://climatechangeconnection.org/emissions/co2-equivalents/

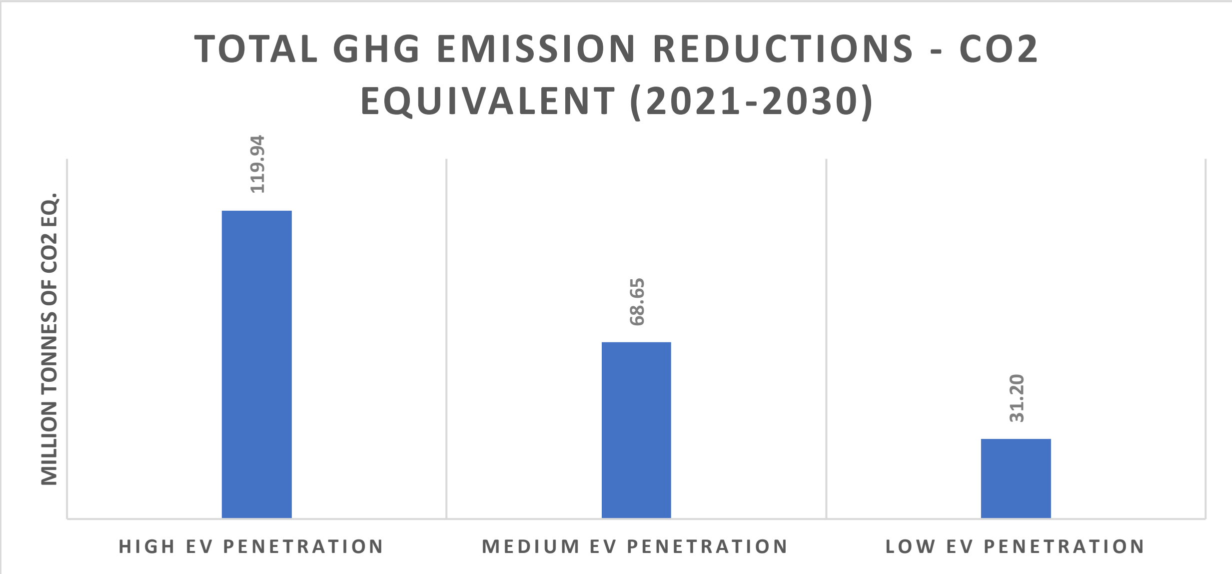

Exhibit 33: Cumulative GHG emission reduction with increased deployment of EVs 2021-2030

GHG Emission Mitigation Potential of EVs

On the basis projected sales, the GHG emission mitigation potential of EVs is measured in the form of reduced demand for fuels with increasing share of EVs using equation 1. Exhibit 33 shows the cumulative emission reduction as a result of EV deployment on the basis of three EV penetration cases through 2030. As shown, the cumulative GHG emission mitigation potential could range between 119 MTCO2-eq. in the best-case scenario and 31 MTCO2-eq. in the case of least EV deployment projection during the period 2021-2030. Exhibit 34 demonstrates EVs' potential climate benefits could range between 10 MTCO2-eq and 40 MTCO2-eq per year by 2030.

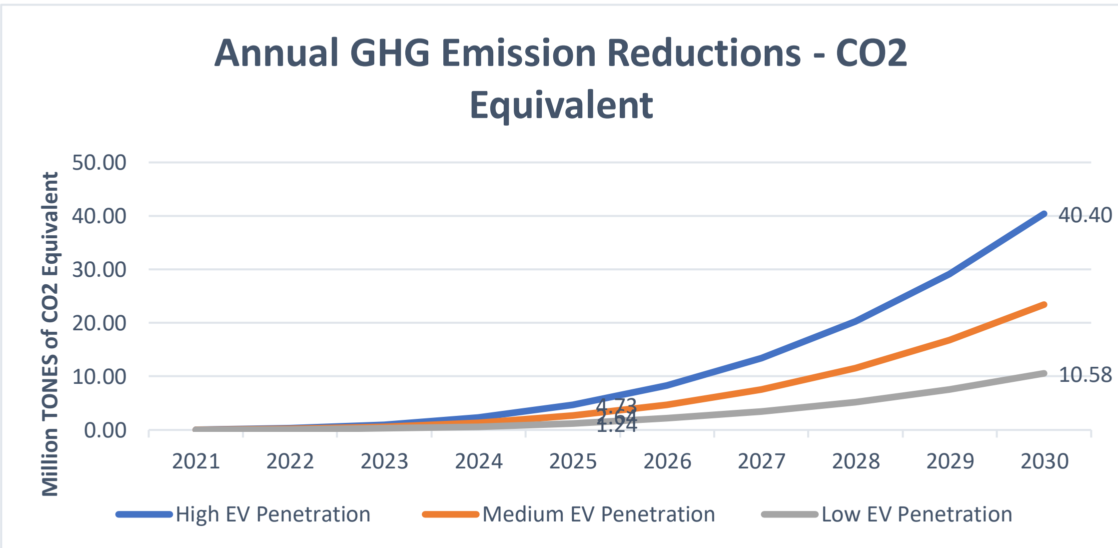

Exhibit 34: Annual GHG emission reduction with increased deployment of EVs through 2030

It may be useful to underline that the estimated GHG emissions for road transport sector in Pakistan totaled at 41.197 MTCO2-eq. in 2015 as reported in the Second National Communication on Climate Change, which is about 10% of the total CO2-eq. of the total GHG emissions in 2015. Overall, the road transport accounts for about 92% of the total emissions from the transport sector.

Subsequently, we compute the GHG emissions of additional electricity demand as a result of increase in EVs during the period 2021-2030. As discussed earlier that direct emission of EVs are zero but they have a footprint for indirect GHG emissions since they use electricity generated from power plants. As most power plants produce emissions, and there are additional emissions associated with the extraction, processing, and distribution of the primary energy sources they use for electricity production.

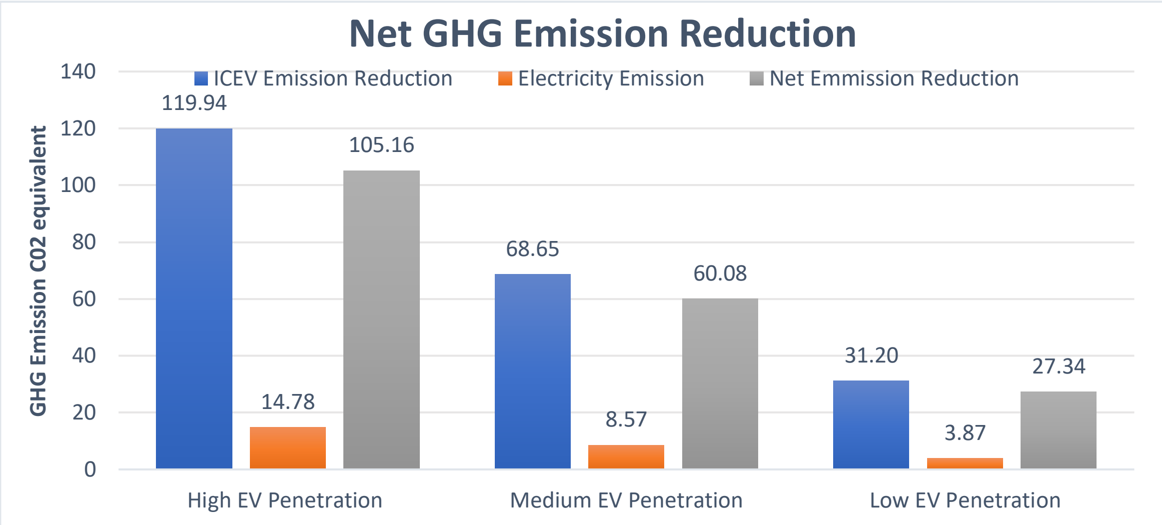

Exhibit 34: Net GHG emission mitigation potential of electric mobility

One approach to measure the GHG emission associated with electric consumption by EVs is to employ the Grid Emission Factor. The grid emission factor measures the carbon emission intensity of grid that is calculated based on the net electricity production (total electricity production minus energy losses) and the total GHG emissions for electricity production.[50] We use this grid emission factor for Pakistan at 0.567tCO2/MWh as published by Institute for Global Environmental Strategies.[51]

Next, we calculate the net GHG emission reduction based on total emissions avoided by switching to EVs minus the GHG emissions associated with electricity consumption for charging EVs. Exhibit 34 reflects that EVs offer tremendous environmental benefits in terms of net emission reduction after

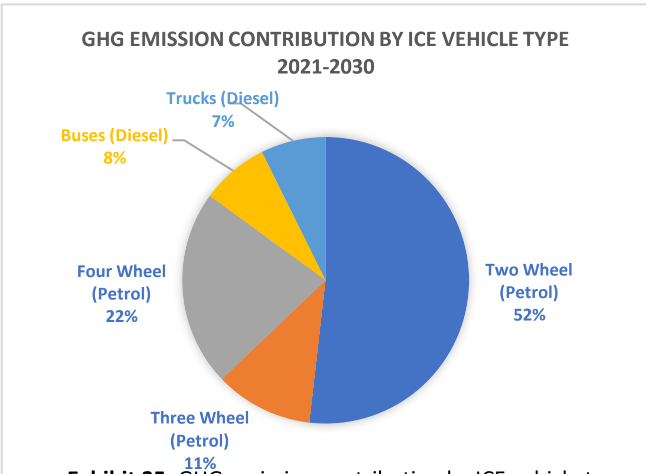

Exhibit 35: GHG emission contribution by ICE vehicle type

[50] E-Mobility Options for ADB Developing Member Countries
51 IGES List of Grid Emission Factors: https://www.iges.or.jp/en/pub/list-grid-emission-factor/en

factoring in the grid emissions. This analysis highlights that climate benefits of electric mobility in Pakistan would continue to increase with further decarbonization of the grid to meet the target of 30% of renewables in total electricity generation as planned under the Alternative and Renewable Energy Policy 2019. Two wheels or motorbikes would play a predominant role towards reducing the GHG emission amongst all other vehicle types in the road sector, as shown in the Exhibit 35.

Chapter – VI: Understanding the Economics of Commercial EV Charging

Public Charging Stations are anticipated to play an important role in accelerating the adoption of EVs. Tariff determination for an electric vehicle charging station is a complicated process and it widely varies depending on type of vehicle, place of parking, and power load and kind of charging facility. For the purpose of this report, our key consideration is the financial viability of commercial EV charging stations.

Firstly, there is a need to recognize that EVs require a distinct consumer category due to its unique characteristics, such as unpredictable and dynamic demand.[52] Secondly, due to their mobile nature, EVs could result in power spikes in certain locations and during specific time of the day.

Thirdly, owing to the Vehicle2Grid (V2G) functionality, EVs could be classified as the Distributed Energy Resource (DERs), and thus they are applicable to bi-directional energy flows.[53] All these unique characteristics must be taken into consideration while determining and designing the electricity tariff for commercial EV charging.

The aforementioned conditions warrant deliberation and classification for introducing dedicated tariff for EV Charging Stations. An adequate tariff rate would allow the EV charging stations to recover the costs while making EV charging cost-effective to an EV owner and enabling charging service a commercially viable business.

Key Cost Components

The EV industry is a nascent one and the commercial EV charging market is in its very early stages. Hence, there is limited data available regarding various cost components, such as equipment cost and site-preparation etc. Furthermore, different players in the value chain are reluctant to share their insights. These facts made it necessary to work with existing information and to form educated estimates of financial scenarios that EV charging station operator may face. The model that we have developed has this flexibility that the user can tweak variables and making amendments to assess the financial viability of charging stations under various scenarios.

There are two fundamental cost components of EV charging stations; capital costs and operating costs. Capital costs include cost of equipment, installation, site preparation and grid connection cost. Typically, these are the fixed costs that the charging station owner or operator has to pay at the time of setting up the charging station.

Operating costs, on the other hand, are variable costs that are associated with operation of the charging station, which includes cost of electricity supply, maintenance, and land lease, and financing costs for interest paid on loans and returns paid to equity investors.

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52 Bhawna, T., & Shyamasis, D. (2020). *Dissecting India's Electricity Tariff Landscape for EV.* Alliance for Energy Efficient Economy.

53 Quentin, H., & Yannick, P. (n.d.). Network tariff design with prosumers and electromobility: who wins, who loses? Paris.

Capital Costs

Capital costs or fixed costs associated with different types of Electric Vehicle Chargers and they have three main components:

1. The cost of the charging equipment or EVSE;
2. The cost of installing the equipment and relevant the cost of site preparation; and
3. Utility system upgrades, such as new transformers, wires and switches.

EV Charger Equipment Cost Estimates (PKR)				
	Level 2 7 kW AC	Level 3 DCFC 50 KW	Level 4 DCFC 150 KW	Level 5 DCFC 350 KW
ABB Pakistan	320,000	4,960,000	11,200,000	19,200,000
SZS Group - Pakistan	225,000	3,000,000	5,500,000	-
Chinese EVSE Supplier	140,000	2,300,000	3,900,000	14,000,000

Exhibit 36: Capital Cost Estimates for Commercial Charging Station

Source: *Author's compilation based on data from Link Charging Technologies, ABB Pakistan, SZS Group Pakistan, and Economic Research Institute for ASEAN and East Asia.*

Exhibit 37 below summarizes make-ready cost estimates for each level of charging.

Make-ready Cost Estimates for Commercial Charging Station (PKR)				
	Level 2 7 kW AC	Level 3 DCFC 50 KW	Level 4 DCFC 150 KW	Level 5 DCFC 350 KW
Site preparation (per charger)	40,000	480,000	480,000	480,000
Installation (per charger)	16,000	50,000	50,000	50,000
Transformer (per station)	0	2,880,000	4,800,000	4,800,000
Distribution Box & Cabling (per station)	0	1,040,000	1,040,000	1,040,000

Exhibit 37: Make-ready cost estimates for commercial charging station

Source: *Author's assumptions and compilation based on data from Link Charging Technologies, ABB Pakistan, Attock Petroleum Limited, SZS Group Pakistan, and Economic Research Institute for ASEAN and East Asia.*

Charging Equipment Costs

Equipment costs varies significantly across manufacturers, charger types, and several estimates are available for each type. Exhibit 36 provides the cost ranges of commercial chargers of various equipment suppliers. Commercial Level 2 EVSE cost ranges between PKR 140,000 and PKR 225,000 for a charger with an electronic interface, payment system, and network connection. DC fast charger are significantly more expensive, typically costing about PKR 2.3 million to PKR 4.9 million for DC Level 3 – 50 kW charger and PKR 3.9 million to PKR 11.2 million for a Level 4 DC 150 kW charger. These cost estimates vary across manufacturers and specifications.

In the U.S., a single 50 KW DCFC charger could cost around PKR 6.6 million. While the cost of same equipment with similar specifications from low cost manufacturers such as some in Asian markets could go as low as PKR 2.3 million. ABB - a European manufacturer, has installed a few 50 KW chargers in Pakistan with an equipment cost of PKR 4.9 million. A list of charging equipment cost estimates for both AC and DC chargers in various countries is provided at **Annex – V.**

Since the costs vary significantly across the manufacturers for the same type of chargers, this poses a challenge for us as to what capital cost ranges do we consider while determining the tariffs for EV charging stations.

Installation and Site Preparation Cost

The installation and site preparation costs are highly location specific and they include electrical service extension, permitting, labor costs, and trenching to lay cables. These costs are generally minimal for Level 2 but these costs can be higher depending on the location, which may require additional installation of a physical post or tower as opposed to wall-mount fixture. In Pakistan, we have not yet found any commercial level 2 installation in the country so far although, worldwide, Level 2 is the most common charging port.

Installation and site preparation costs for commercial DC fast chargers of Level 3 is much higher than Level 2 charging stations. A Level 3 DCFC station may require major preparation in the form of wiring extensions and trenching to install the additional connections to the grid. We believe these costs would vary and they would be highly location specific, since each charging station and location might have unique requirements. Thus, the range of cost estimates for site preparation and installation could vary based on the location. For this analysis, we are using cost estimates for site preparation and civil work that we obtained from ABB since they have already installed a number of chargers in Pakistan. These cost estimates are provided as provided in Exhibit 37 above and we believe these costs may be on the higher side.

Grid Connection Cost - Transformer

Grid connection with supply of a dedicated transformer is a major cost component of a charging station. It is associated with grid infrastructure upgrade that a power distribution company is required to provide service to the charging station. For Level 2 charging stations, these upgrades will be minimal or unnecessary; hence we do not assume any grid connection cost for Level 2.

Though a single Level 2 charger would not require a transformer upgrade, but several Level 2 chargers operating simultaneously on the same network can be overloaded, and thus require a dedicated transformer.

The grid connection costs are much higher for DCFC Level 3 and Level 4 charging stations, as it would require a dedicated transformer for these stations. This grid connection cost will be a major cost component of the charging stations at Level 3 and beyond. Cost of a transformer would largely depend on the number of DC fast chargers installed. Thus, with increasing peak demand, the infrastructure needs would be greater, will be higher as number of chargers increases on any station. For level 3 charging station, we are assuming 3 DC fast chargers of 50 kW each and these would require an installation of 200 kVA transformer at a cost of PKR 2.8 million to meet the load requirement. Similarly, for level 4, we assume 2 chargers with 150 kW capacity each and 400 kVA transformer at a cost of PKR 4.8 million to manage the required load.

In this analysis, we are not considering 350 kW DC fast charger, as we believe there would be only a few vehicles on the Pakistan roads with capability to absorb DC fast charging at power capacity of 200 kW and above. So far only a few variants, such as by Tesla and Porsche can handle such a high amount of DC fast charging. Yet we might be able to see some heavy-duty vehicles such as buses and trucks in the future with power demand exceeding 300 kW but that is not happening any time soon.

Distribution Box and Cabling

In certain locations, it may require further infrastructure upgrades in terms of extending cables from the transformer to the distribution box and chargers. Generally, this may involve installation costs of distribution box and extending new cables from the transformer. We have assumed this cost to be at approximately PKR 1 million for DC Level 3 and 4 chargers. Whereas, for the Level 2 chargers, we do not consider the need for similar installations.

Operating Costs

Operating costs are variable costs that are associated with operation of the charging station, which includes costs for electricity, maintenance, and land lease; and financing costs for interest paid on loans and returns paid to equity investors.

Cost of Electricity Supply

This is the cost of electricity supply to the operator of charging facility which is measured in PKR per kWh consumed for charging EVs. The station operator or owner would have to pay back this cost to the DISCO. With the addition of EVs as a new set of consumers, it warrants a preferential tariff for EV charging to promote EV adoption in the early stages of market development.

Governments around the world are providing a number of subsidies for both commercial and residential EV chargers. For example, in Germany, EV charging operators receive a grant that covers up to €2500 per AC charging station (up to 22 kW) bought or leased. Alternatively, up to €30,000 in funding can be applied for per DC fast charging station (50 kW and above). While, the US Federal Tax Credit gives business 30% of the total cost of purchasing and installing an EV charging station to claim the credit on federal tax return with a maximum ceiling of US $30,000.[54] In China, some provinces and cities support installing charging stations via subsidies. The most generous subsidy could reach 30 percent of the total investment.[55]

In case of Pakistan, the incentives are limited to low customs duties at 1% on import of charging equipment, and proposed exemption of income tax and general sales tax for EV charging stations. Hence, in order to offer lower charging rates to EV consumers, especially during the initial rollout period; we recommend that EV charging stations shall be offered lowest possible cost of electricity supply.

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[54] **ChargePoint**, Electric Vehicle (EV) Charging Incentives. https://www.chargepoint.com/incentives/commercial/?type=13&state=19

[55] **Environmental and Energy Study Institute**, Comparing U.S. and Chinese Electric Vehicle Policies. https://www.eesi.org/articles/view/comparing-u.s.-and-chinese-electric-vehicle-policies

Ideally, EV charging stations may be offered lower rates preferably in line with industrial rates for the next 2-3 years to help boost EV adoption in the country. In case of India, EV specific tariffs (electricity supply cost to charging station) varies between 5 US cents/kWh to 8 US cents/kWh. In most cases, EV specific tariffs are higher than residential rates but lower than commercial tariffs.[56] The tariff determined and incentives provided in terms of lower cost of electricity supply to charging stations may also be periodically reviewed and adjusted based on market growth and development.

For the purpose of this analysis, we use Time of Use (ToU) tariff rates with an off-peak rate of PRK 15 per kWh, and peak rates at PKR 20 per kWh (adapted from IESCO's[57] industrial rates). On the bases of this pricing, model assumes a 70% of charging session takes place during the off-peak periods.

ToU pricing can be an effective strategy to manage the grid impact by incentivizing the EV owners to adopt optimized charging behaviors. If the overwhelming majority of EV owners are encouraged to charge at off-peak hours, it will eliminate the need for investments in higher-voltage and more-expensive transmission circuits and substations. In some cases, ToU rates have been found effective enough to minimize the overall need for new power generation investment.

Off-peak charging would limit the number of substations that would be needed as well as eliminate the need for installation of new capacity of circuits, switches, and distribution transformers.[58]

Demand Charge Costs

Demand charges reflect the projected cost to the utility of providing the generation and distribution infrastructure required to meet peak demand on both a system level and a local distributional level. Demand charge is tied to the peak electricity demand during on-peak hours within a month. For instance, the IESCO levies demand the charge of 440/kW/month from the commercial consumers.

Worldwide experience shows that demand charges heavily impact the economics of early-stage electric-vehicle charging rollouts. In India, many states have announced no demand charge in order to boost EV adoption.[59] In addition, many utilities around the world already offer to reduce or eliminate their demand charge for EV charging stations. Hence, for the purpose of tariff determination, we propose the demand charges to be waived off initially for 2-3 years to help promote EV adoption in Pakistan. Since there are multiple economic, environmental, and social benefits to increased adoption of EVs and charging stations, which would translate into more electric customers and thus, higher revenues for the DISCOs.

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[56] **Bhawna Tyagi and Shyamasis Das,** "Dissecting India's Electricity Tariff Landscape for EVs" (2020) https://aeee.in/wp-content/uploads/2020/07/2020-Dissecting-India's-Electricity-Tariff-Landscape-For-EV-1.pdf
[57] **Islamabad Electric Supply Company (IESCO)** – a power utility company that serves in Islamabad and adjacent jurisdictions. https://iesco.com.pk/index.php/customer-services/tariff-guide
[58] **Boston Consulting Group**, "The Costs of Revving Up the Grid for Electric Vehicles" (2019) https://www.bcg.com/publications/2019/costs-revving-up-the-grid-for-electric-vehicles
[59] **Bhawna Tyagi and Shyamasis Das,** "Dissecting India's Electricity Tariff Landscape for EVs" (2020) https://aeee.in/wp-content/uploads/2020/07/2020-Dissecting-India's-Electricity-Tariff-Landscape-For-EV-1.pdf

Maintenance Costs

General maintenance for charging infrastructure includes storing charging cables securely, checking parts periodically, and keeping the equipment clean. Chargers may need intermittent repairs as well. While ongoing charging infrastructure maintenance can be minimal, repairing broken chargers can be costly if they are no longer under warranty. While actual maintenance costs vary, international experience estimate maintenance costs of up to $400 annually, per charger.[60]

Maintenance and warranty/ insurance costs vary according to charger type and location. These costs are typically more expensive for fast chargers with components under greater physical strain and at greater risk of vandalism or other physical damage. We propose annual maintenance cost as 1% of the total equipment cost.

General and Administrative Costs

These are administration costs to support sales and operation of a charging station. Administrative costs would vary depending on the type and number of chargers installed for any certain charging station. At the moment, we do not have reliable data regarding this cost element and thus, relying on estimates and guesses. For this analysis, we assume sales, general, and administrative costs at 5% of revenue of charging station.

Land Lease Costs

The charging station operator would have to arrange the ground lease agreement with the property/land owner for parking spaces to install the charging equipment. The host (property owner) can contract for a term of 10 years, and charge a ground lease at mutually agreed terms between the host and station operator.

We believe the majority of Level 3 and Level 4 DC Fast chargers would be installed at facilities which are already built, e.g. the rest areas along the motorways/highways, and at existing petrol stations, whereas for Level 2, chargers would most likely be installed at parking spaces of commercial areas/shopping malls, and workspaces etc. In both of these cases, most preferred option for a charging station operator would be to lease the land. But we cannot rule out the option of purchase of land.

Since there is limited information available for this variable, the model assumes the nominal annual cost of leasing land at PKR 300,000 for each Level 3 and Level 4 DC charger. While for the Level 2 charging station, we believe this could be cheaper as station operator would conveniently use the existing parking space at an already built location. Hence, we assume land lease cost at PKR 100,000 annually for each Level 2 charger. So, for the Level 3 or Level 4 charging station which has 3 chargers, the total annual land lease cost for the entire station would be PKR 900,000. Land lease would also

[60] **US Department of Energy**, "Charging Infrastructure Operation and Maintenance" https://afdc.energy.gov/fuels/electricity_infrastructure_maintenance_and_operation.html

vary significantly from city to city and it can also vary within a city depending on the actual location of the charging station. Thus, it is a bit tricky to establish a uniform benchmark for this cost parameter.

Modeling the Financial Viability of Charging Stations

The purpose of this report is to analyze the profitability of commercial EV charging stations from the site owner's perspective. This analysis is meant to assist National Electric Power Regulatory Authority (NEPRA) in its determination of electricity tariff for EV charging station and decide on adequate profit margin for the operators or owners.

To evaluate profitability, a Net Present Value (NPV) and Internal Rate of Return (IRR) analysis is conducted using a discounted cash flow (DCF) model. On the basis of considered inputs and assumptions, the model generates results to gain insights as to how much a markup on electricity sale that a charging station operator need to charge from EV owners in order to make a decent return on investments.

Discounted Cashflow Model

A Discounted Cash Flow (DCF) analysis is a commonly used method in finance to value a project, company, or asset. Incoming and outgoing cash flows are estimated and then a discount rate is applied to those cash flows to arrive at a present value. The sum of those present values is the Net Present Value or NPV. We developed a DCF analysis model for three different types of scenarios for these commercial charging station.

These scenarios are as follows:
1) Scenario 1: Level 2 7 kW AC Commercial Charging Station with 5 chargers
2) Scenario 2: Level 3 50 KW DCFC Local Charging Station with 3 chargers
3) Scenario 3: Level 4 150 KW DCFC at a major motorway/highway with 2 chargers

The DCF model is valuable because it considers the time value of money, which is the idea that money in the present is more valuable than the same amount of money in the future due to the ability of money to earn interest. The Internal Rate of Return (IRR), which is the rate of return that makes the NPV zero, will also be used to assess each charging scenario.

Revenue is computed as a function of utilization rates and electricity sale, and measured in PKR/kWh. Utilization rate of a charging station is the amount of time during which the charger is plugged in to charge an EV. E.g. a utilization rate at 20% means that a charger is being used for roughly five hours in a day. On the cost side, we use equipment and installation costs, cost of electricity supply, and cost of capital as the main items impacting the financial model. Annex - III has full list of assumptions and inputs we have used for all three scenarios.

A markup is applied by the station owner/operator on each kWh of electricity at the point of sale. We call it as the "final price." For example, if electricity costs the station operator PKR 15/kWh on average and the markup required for the project to cover all costs is PKR 12/kWh, operator will need to charge a minimum final price of PKR 27/kWh to break even.

In this model, we employ Time of Use tariff regime with off-peak and peak electricity rates. The model assumes that 70% of the charging take place during the off-peak hours and remaining 30% during peak hours. For off-peak sessions, we use cost of electricity to station operator at PKR 15/kWh and for peak, PKR 20/kWh for all three scenarios. These are realistic assumptions and estimates based existing tariff rates of IESCO for its industrial consumers.

Although we recommend that markup or profit margin for site owner as decided or determined by the power regulator should remain constant regardless whether the charging take place at off-peak or peak hours. ToU pricing is primarily meant to manage the peak load to reduce grid impact; therefore, it should not have any impact on the profitability of charging station operator.

Cost of Capital

The model uses Weighted Average Cost of Capital (WACC) method as a key input into DCF analysis. The WACC is the rate at which future cash flows need to be discounted to arrive at a present value for the business. WACC is calculated by multiplying the cost of each capital source; debt and equity by its relevant weight by market value, and then adding the products together to determine the total.

We assume the station operator uses 70% debt and 30% equity to run its business. Assuming those charging stations are eligible for lower interest rates as recommended by the Economic Coordination Committee (ECC), we take 5% interest rate as cost of debt. While for cost of equity, we use Capital Asset Pricing Model (CAPM) which is a framework for quantifying cost of equity and it is governed by following equation:

$$\text{Cost of equity} = \text{Risk free rate} + [\beta \times \text{Equity Risk Premium (ERP)}]$$

Whereas, $\beta = 1$ ("beta") is company's sensitivity to systematic risk. ERP is the incremental risk of investing in equities over risk free securities. We have taken the risk-free rate at 1.38% with beta equal to 1.316 and Equity Risk Premium at 5%. Based on these assumptions and inputs, the WACC comes around 8%.

Charging Station Utilization

Utilization refers to the amount of time that the station is in use providing electricity to a vehicle as a percent of the total time the station is theoretically available. A charger that is in continuous use over a 24-hour period has a utilization of 100% while a charger that is used only one hour per day has a utilization of 4% (1/24).

Utilization of an EV charging station is mainly dependent on EV sales in the future. Although forecasting EV sales into the future is challenging given that this is an emerging industry with limited history and that future sales are dependent on a large number of factors, including purchase cost of EVs relative to the comparable ICE vehicles, price of fuel to electricity, availability, range and performance of EVs, fiscal, regulatory and policy incentives for EVs etc.

Based on international experience the utilization of charging stations varies significantly by location and type of chargers. As EV penetration in a certain area increases the utilization of stations in that area increases. Utilization rates can go as high as 50% for public stations for efficiently managed electric fleets and urban locations with considerable higher concentration of EVs.[61]

Currently, a few oil majors, including Pakistan State Oil (PSO), Attack and Go Petroleum have installed Level 3 - 50 kW DC fast chargers at their fueling stations in Islamabad, Lahore and Karachi. Based on our consultation with these retailers, we propose the utilization rate of 20-25% for the purpose of tariff determination for DC Level 3 and Level 4 chargers. we have assumed utilization rates of at least 20% on average for our calculations of the network economics. The model assumes an average charging session of 20 minutes and 30 minutes for Level 4 – 150 kW and Level 3 - 150 kW respectively. Whereas for Level 2 - 7 kW AC, we assume an average charging session of 120 minutes. These typically experience higher daytime and evening use and we propose utilization rate of Level 2 chargers at 30%.

Worldwide experience shows that the utilization rates for DC Level 3 and DC Level 4 lie within the range between 10% and 25%.[62] In practice, the DC fast charging industry uses a 20% utilization as a rule of thumb for DC fast chargers and this utilization rate is expected to increase to 30% by 2027.[63] For AC Level 2 charging, the utilization is expected to be even higher in the range of 30-40% in developed markets. In some of the European countries, Level 2 AC chargers have achieved utilization rates of over 50%.[64]

International market suggests that for a charging station with utilization at 10%, commercial chargers are almost universally not economically profitable, suggesting a significant, sustained increase in demand will be needed for commercial charging infrastructure to deliver financial returns, and compete with both ICEs and cheaper residential charging.[65]

For DC fast chargers, demand charges can dominate operating costs. As a result, the total cost of power from fast charging stations is higher than slower residential chargers. In the early stages, we recommend that demand chargers should be kept at the minimum level or may waived off altogether to encourage investments into the charging infrastructure and to reduce the final price to the end consumers.

Returns-to-scale may help to offset some capital costs. Charging stations with greater numbers of chargers will have proportionally higher demand charges. Hence, a multi-charger station would incur lower per-charger capital costs than a standalone charger. This is due to the fact that the utility service extensions and grid upgrades will only be required once at the time of installation.

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[61] **Rocky Mountain Institute**, "EV Charging Infrastructure" (2020). https://rmi.org/wp-content/uploads/2020/07/EV-Readiness-Guide_Haryana_Lighthouse_Discom_Programme.pdf

[62] **PWC**, Electric vehicles and the charging infrastructure: a new mindset? (2021) https://www.pwc.com/us/en/industrial-products/publications/assets/pwc-electric-vehicles-charging-infrastructure-mindset.pdf

[63] **Garrett Fitzgerald and Chris Nelder,** "Evgo Fleet and Tariff Analysis" Rocky Mountain Institute (2017) https://rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf

[64] **Virta Global**, How are we charging? – A deep dive into the EV charging station utilization rates (2020) https://www.virta.global/blog/how-are-we-charging-a-deep-dive-into-the-ev-charging-station-utilization-rates

[65] **Henry Lee and Alex Clark**, "Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption" Harvard Kennedy School (2018), https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf

Profitability Analysis

After developing this DCF model based on the factors outlined above, we conducted a sensitivity analysis to determine a range of scenarios likely to be faced by station operators. Utilization is the single most important variable with the greatest impact on financial viability of charging station. Once an EV-charging station is built, all costs are essentially fixed, so utilization is key to achieving efficiency. Hence, we plot the levelized charging cost to the consumer in PKR/kWh with respect to varying charging station utilization rates. It is the price that a charging station operator would have to charge from an end consumer to achieve 15% IRR as illustrated in Exhibit 38. These levelized costs are inclusive of both peak and off-peak rates for all three charging stations based on equipment cost estimates provided by SZS group.

At this point, it is important to consider as what to is the potential cost ceiling and below which consumers should be willing to pay for charging an EV at a commercial station. We factor in this "willingness to pay" as a price range between a fuel cost for an ICE vehicle and residential charging, which is the cheapest option available to an EV owner. So, charging should always be cheaper than fuel cost equivalent of ICE vehicle. It would also be an interesting to include cost equivalent of Hybrid vehicle.

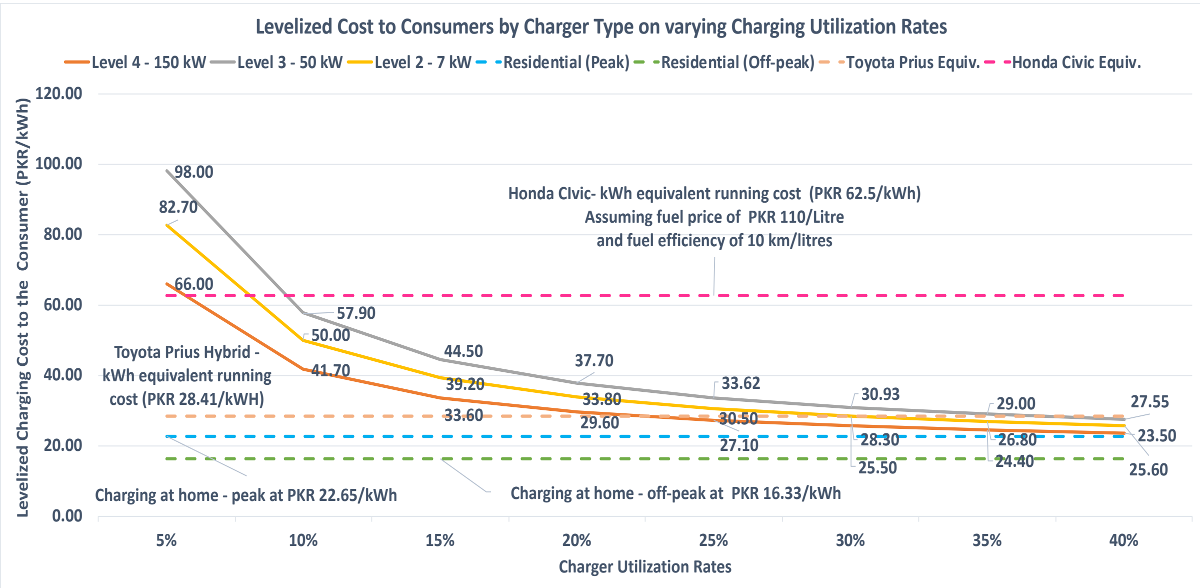

Exhibit 38: Levelized Cost to Consumers by Charger Type at an IRR of 15% on varying charging utilization rates.

Fuel costs are plotted for a Honda Civic (fuel efficiency at 10 km/liter) at PKR 62.5 per kWh equivalent and for a Toyota Prius Hybrid (fuel efficiency at 22 km/liter), PKR 28.4 per kWh-equivalent as illustrated in Exhibit 38. The method of deriving these numbers is as follows:

- An EV with 44 kWh battery is assumed to cover 250 km per full charge
- Assuming petrol price of PKR 110/liter and mileage of 10 km/liter for a Honda Civic, the equivalent fuel cost to cover 250 km is PKR 2,750.
- The kWh-equivalent of this petrol cost is PKR 2,750/44 kWh = PKR 62.5/kWh

- Similarly, we run the same calculation for a hybrid vehicle at fuel efficiency of 22 km/liter. The kWh-equivalent cost for Toyota Prius is PKR 28.4/kWh.

This analysis demonstrates that Level 4 - 150 kW perform better on price than Level 3 for lower levels of utilization. It is due to the fact that 150 kW injects more electricity than 50 KW charger in a given level of utilization and hence, it is able to produce higher sales which offsets the higher capital costs. Thus, it suggests that for higher levels of power, a given level of utilization produces more additional revenue than additional cost, hence lowering the average margin the operator must make to break even. At progressively higher levels of utilization, there is a sharp decrease of breakeven price.

At 10% utilization, the charging costs for all three scenarios is below the equivalent cost for an ICE vehicle i.e. Honda Civic. At 20% utilization and above, all charging stations are much cheaper than the ICE vehicle but only at 40% utilization, Level 4 achieves cost competitiveness relative to residential charging at peak rates. No level of commercial charging is competitive with residential charging under off-peak rates.

Pricing Models and Principles

EV Tariff Rate Design Models

Many countries have adopted different tariff regimes or models appropriate to their respective needs. The tariff design model varies depending on how customers pay for charging their cars. Currently, the following tariff models are in practice worldwide for public EV charging stations:

1. **Flat Rate Model:** Through this tariff structure, consumers are charged at a flat rate per unit (kWh) of electricity consumed. Flat rates can also be used with some rebate for delayed charging to encourage consumers to shift to off-peak hours.[66]

2. **Time of Use (ToU) Model:** Through this regime, consumers are charged for lower cost per unit (kWh) of electricity consumed during certain hours of the day and higher during the peak hours. This is often a useful tool to incentivize EV consumers to delay charging to off-peak hours. Thus, the ToU model is effective for distribution companies and regulators to flatten the load curves.[67]

3. **Pay per Time + Energy Use model:** This tariff structure is effective in differentiating between a fast charging versus slow charging methods.[68] This works best in conditions in which a car has completed charging, but remains idly plugged in to the charging cable, and is using up space without generating revenue. Hence, this model is useful to disincentivize consumers to not to plug in their EVs for long durations. Consumers have to pay even higher for the same amount of time during the peak hours. The model we have developed has this flexibility to use this pricing option in addition to volumetric electricity sale.

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[66] Matteo, M., Eleftheria, K., & Joshua, E. (2019). Electricity rates for electric vehicle direct current fast charging in the United States. Renewable and Sustainable Energy Reviews.

[67] Sioshansi, R. (2012). Modeling the Impacts of Electricity Tariffs on Plug-in Hybrid Electric Vehicle Charging, Costs, and Emissions. *Operations Research*, 1-11.

[68] European Investment Bank. (2018). Financing innovation in clean and sustainable mobility Study on access to finance for the innovative road transport sector. Kirchberg, Luxembourg: European Investment Bank.

4. **Real Time or Dynamic Pricing:** EV owners are charged based on the real-time cost of energy.

5. **Cross-subsidized models:** In some cases, retail owners, businesses and university campuses offer charging facilities either at no charge or subsidized rates to encourage the ownership of EVs amongst their employees. In return, such businesses apply for green certificates which are applicable to lower taxes. This model has been used in some of the European countries and the UK.[69]

General Considerations for Tariff Design for EV Charging

We should recognize that creating a business opportunity for companies that provide public EV charging services is a societal goal. It should be considered in the same fashion as providing drivers with access to petrol refueling stations. Thus, the charging station operator should be able to earn a reasonable profit by providing a valuable service and maintaining the charging equipment in working condition. EV charging stations and electricity tariffs for such stations should have the following characteristics:

1. Commercial Charging should be profitable so that it is sustainable. EV chargers should be on dedicated tariffs and on separate meters, preferably the meter built into the charging station. Charging should be cheaper than petrol equivalent cost (PKR 62/kWh)
2. EV chargers should use time-varying volumetric rates for electricity, such as a Time of Use (ToU) rate. Ideally, these volumetric charges should recover nearly all the cost of providing energy and system capacity. The highest-cost periods of the ToU tariff should coincide with the periods of highest system demand (or congestion).
3. Level 2 AC charging should be considerably cheaper than Level 3 and Level 4 DC fast charging.
4. Distribution Companies (DISCOs) should offer low fixed charges, which primarily reflect routine costs for things like maintenance and billing.
5. In certain conditions, DISCOs could offer low rates for public charging stations installed in overbuilt and underutilized areas of the grid, in order to increase the efficiency of existing infrastructure and build new EV charging infrastructure at low cost.
6. Demand charge is a key instrument to tackle a surge or spike in EV power demand. However, the demand charge needs to be appropriately designed to enable charging service as a viable business opportunity for an investor and also to avoid making EV adoption unattractive for an EV owner.
7. Some portion of the grid upgradation cost could be justifiably recovered from the general public or customer base, because public charging stations provide a public good in the form of reduced air pollution and other local economic benefits.

[69] KYOS. (2020). What is green certificate? Retrieved from KYOS - Our Analytics Your Advantage: https://www.kyos.com/faq/green-certificate/

For the purpose of tariff determination, NEPRA may consider following categories in accordance with power capacity usage and distinct utility function for a public charging station:

Sr. No	Charging Levels	Power Capacity (kW)	Preferred Locations
1	Level 2 (Standard)	7 kW	Workspaces/ Businesses/Shopping Mall
2	Level 2 (Maximum)	22 kW	Commercial - Shopping Malls/Workspaces
3	Level 3 DCFC	50 kW	Major urban centers – city metropolitans/ highways
4	Level 4 DCFC	150 kW	Highway/Motorways

Exhibit 39: Proposed tariff classifications for EV charging stations.

In majority of cases, residential customers would pay prevalent residential rates for EV charging through standard domestic plugs. However, in some cases, home owners may want to install fast chargers at level 2 (7-22 KW). Thus, they may also be allowed to install Level 2 charger with a separate meter for domestic use and they may be charged at commercial rate. A needs assessment for public charging stations should be carried out based on population and type of electric vehicles in any given area, and in close proximity to any business or commercial activity.

Business Models for Commercial EV Charging

Worldwide, there are three primary revenue models for network operators which are described by the following themes: Prepaid, Club Membership, and the Cell Phone.

1. **The Prepaid model** allows EV owners to prepay a fixed amount for unlimited access to charging station within the network. EV charging operator offers a prepaid plan at fixed rate for unlimited charging for a given duration.
2. The **Club Membership model** where EV owners pay a small monthly fee plus the electricity cost per charge.
3. The third is a **Cell Phone model** which derives similarity from wireless carrier plans. This model offers EV drivers a combined home and public charging plan. They are offered by energy and utility companies to EV drivers with a public/private solution. EV owners can choose among a number of plans that offer a combination of home charging and public charging, plus the electricity cost.

EV Charging Rates in Selected Countries

India

In India, the setting up of Public Charging Stations has been de-licensed and any individual/entity is free to set up public charging stations, provided the stations meet the technical as well as performance standards laid down by the Government of India.

In India, the tariff-setting is a state-subject i.e. the State Electricity Regulatory Commission (SERC) in each state is responsible for determining tariffs for different consumer categories. The energy and demand charges for EV charging which are two parts of the tariff, are found to vary across states.

However, the National Tariff Policy remains the overarching guidance for the SERCs to fix tariffs, according to which consumer tariffs should be brought within +/- 20% of the Average Cost of Supply.[70] For Level 2 AC tariff, average tariff is lower than $0.18/kWh. EV specific tariffs are higher than residential rates and lower than commercial tariffs. In most cases, EV charging tariffs have a flat energy rate (no consumption-based slab) irrespective of the type of connection. The average tariff for Level 3 - 50 kW DC Fast Charger ranges between $0.19/kWh to $0.26/kWh.[71]

USA

The cost to charge an EV varies widely in the U.S. The key factors include differences in the price of electricity, the types of equipment used, and the cost of installation. The national average cost to charge an EV range from $0.08/kWh to $0.29/kWh, with an average of $0.15/kWh.[72]

The average cost of $0.15/kWh assumes 81% of charging was done at home, 14% at the workplace or public station, and 5% with a DC fast charger (DCFC). Exclusively charging at DC fast charging stations increases the national Levelized Cost of Charging Stations (LCOC) by 83% to $0.27/kWh from $0.15/kWh.

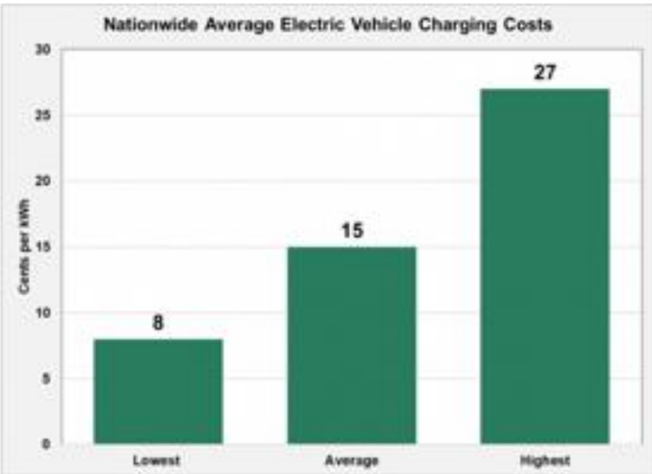


Exhibit 40: Nation Wide Average Electricity Tariff for the EVs in the USA. (Source: InsideEVs)

[70] Alliance for an Energy Efficient Economy, Dissecting India's Electricity Tariff Landscape for EV (2020) https://aeee.in/wp-content/uploads/2020/07/2020-Dissecting-India's-Electricity-Tariff-Landscape-For-EV-1.pdf

[71] Fortum, Pricing List EV Charging Services (2020), https://www.fortum.in/products-services/vehicle-charging/pricing-list-and-terms-conditions

[72] National Renewable Energy Laboratory, "Levelized Cost of Charging Electric Vehicles in the United States" (2020) https://www.cell.com/joule/pdfExtended/S2542-4351(20)30231-2

China

EV charging rates in China have been set at relatively low levels in order to encourage uptake of EVs. First, the residential customers pay the residential rate, which is typically one of the lowest tariffs. Second, dedicated central EV charging and battery swap stations pay the large industrial customer rate, except they are exempt from the demand charge. Third, government offices, public parking lots and other businesses pay the commercial and small/medium industrial (C&I) rate, which is typically the highest tariff.

Many Chinese provinces and cities have time-of-use rates for EV charging. State Grid uses time-of-use pricing at its own charging stations. In Beijing, the State Grid charges $0.15/kWh at peak periods, US$0.11/kWh at partial periods and $0.06/kWh at off-peak periods while adding a uniform $0.12/kWh as a service fee.[73]

Europe

In general, electricity prices in Europe are higher than electricity prices in Pakistan. In France, electricity costs about 0.21/kWh for residential charging, and $0.265/kWh at Tesla Superchargers. In Germany, electricity costs $0.33kWh for residential, and $0.365/kWh at Tesla Superchargers.

IONITY is a DC Fast Charging Network for EVs. It is a joint venture founded by the BMW Group, Daimler AG, Ford Motor Company and Volkswagen Group to facilitate long-distance travel across Europe. Through this network, Mercedes-Benz charges at $0.32/kWh at IONITY chargers, with no annual subscription fee for the first year. Audi Charging Service costs $0.36/kWh plus a monthly subscription of $19.84, and Porsche Charging Service costs $0.36/kWh plus a basic annual fee of $198.

[73] Anders Hove And David Sandalow, "Electric Vehicle Charging In China And The United States" (2019), Center on Global Energy Policy, Columbia https://energypolicy.columbia.edu/sites/default/files/file-uploads/EV_ChargingChina-CGEP_Report_Final.pdf

ANNEURES

Annex – I Description of IEC Standard for EV Chargers

Portable Charger

- **IEC 62752:** In-cable control and protection device for mode 2 charging of electric road vehicles (IC-CPD)

AC/DC Charger

- **IEC 61851-1:2017** applies to EV supply equipment for charging electric road vehicles, with a rated supply voltage up to 1,000 V AC or up to 1,500 V DC and a rated output voltage up to 1,000 V AC or up to 1,500 V DC. Electric vehicles (EV) cover all road vehicles, including plug-in hybrid road vehicles (PHEV), that derive all or part of their energy from on-board rechargeable energy storage systems (RESS). The aspects covered in this standard include:
  - the characteristics and operating conditions of the EV supply equipment;
  - the specification of the connection between the EV supply equipment and the EV;
  - the requirements for electrical safety for the EV supply equipment.

- **IEC 61851-21-2:2018** defines the Electromagnetic Compatibility (EMC) requirements for any off-board components or equipment of such systems used to supply or charge electric vehicles with electric power by conductive power transfer (CPT), with a rated input voltage, according to IEC 60038:2009, up to 1,000 V AC or 1,500 V DC and an output voltage up to 1,000 V AC or 1,500 V DC. This standard covers off-board charging equipment for mode 1, mode 2, mode 3 and mode 4 charging as defined in IEC 61851-1:2017.

- **IEC 62196-1:2014** is applicable to plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies for electric vehicles, herein referred to as "accessories", intended for use in conductive charging systems which incorporate control means, with a rated operating voltage not exceeding:
  - 690 V AC. 50 Hz to 60 Hz, at a rated current not exceeding 250 A;
  - 1 500 V DC. at a rated current not exceeding 400 A.

- **IEC 62196-2:2016** applies to plugs, socket-outlets, vehicle connectors and vehicle inlets with pins and contact-tubes of standardized configurations, herein referred to as accessories. They have a nominal rated operating voltage not exceeding 480 V AC., 50 Hz to 60 Hz, and a rated current not exceeding 63 A three-phase or 70 A single phase, for use in conductive charging of electric vehicles.

DC Fast Charger

- **IEC 61851-23:2014**, gives the requirements for DC. EV charging stations, for conductive connection to the vehicle, with an AC or DC input voltage up to 1,000 V AC. and up to 1,500 V DC according to IEC 60038. It provides the general requirements for the control communication between a DC. EV charging station and an EV. The requirements for digital communication between DC. EV charging station and electric vehicle for control of DC charging is defined in IEC 61851-24.

- **IEC 62196-3:2014** is applicable to vehicle couplers with pins and contact-tubes of standardized configuration, herein also referred to as "accessories", intended for use in electric vehicle conductive charging systems which incorporate control means, with rated operating voltage up to 1,500 V DC and rated current up to 250 A, and 1,000 V AC. and rated current up to 250 A. This part of IEC 62196 applies to high power DC interfaces and combined AC/DC. interfaces of vehicle couplers specified in IEC 62196-1:2014, and intended for use in conductive charging systems for circuits specified in IEC 61851-1:2010, and IEC 61851-23:2014.

Annex – II Electric Vehicle Charging and Batteries Standards adopted by PSQCA

1.	PS IEC:61851-1	Electrical appliances and accessories (TC-3)	Electric vehicle conductive charging system - Part 1: General requirements
2.	PS IEC:61851-23	Electrical appliances and accessories (TC -3)	Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station.
3.	IEC:62840-1	Dry cells batteries and accumulators (TC -6)	Electric vehicle battery swap system - Part 1: General and guidance
4.	IEC:62840-2	Dry Cell batteries and Accumulators (TC - 6)	Electric vehicle battery swap system - Part 2: Safety requirements.
5.	PS:206-1	Dry cells batteries and accumulators (TC -6)	Lead acid starter batteries part -1 general requirement and method of test
6.	PS:206-2	Dry cells batteries and accumulators (TC -6)	Lead acid starter batteries part-2 dimension of batteries and marking of terminals
7.	PS IEC:62133-1	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 1: Nickel systems.
8.	PS IEC:62133-2	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications - Part 2: Lithium systems.
9.	PS IEC:61960-3	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications - Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them.
10	PS IEC:60622	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes -sealed nickel cadmium prelatic recharge able single cells
11	PS IEC:61951-1	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 1: Nickel-cadmium
12	PS IEC:61951-2	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 2: Nickel-Metal Hydride
13.	PS IEC:61982	Dry Cell batteries and Accumulators (TC -6)	Secondary batteries (except lithium) for the propulsion of electric road vehicles - Performance and endurance tests
14.	PS IEC:60086-4	Dry Cell batteries and Accumulators (TC -6)	Primary batteries - Part 4: Safety of lithium batteries
15.	PS IEC:62620	Dry cells batteries and accumulators (TC -6)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications.

Annex - III Discounted Cash Flow Model Assumptions and Inputs

Capacity Utilization Assumptions of Public Charging Stations

Expected equipment lifespan [years] - All equipment types	10	10	10

Charging Station Assumptions

Charging station type	Level 4 - 150 KW	Level 3 - 50 KW	Level 2 AC 7 KW
Charging Station Capital Cost			
Equipment costs			
Charging station equipment cost (per charger) [PKR]	Rs 205,000	Rs 2,900,000	Rs 5,200,000
Installation and siting costs			
Site Preparation Cost (per charger) [PKR]	Rs 40,000	Rs 40,000	Rs 480,000
Installation Cost (per charger) [PKR]	Rs 16,000	Rs 48,000	Rs 48,000
Grid Upgradation Cost - Transformer (per site) [PKR]	Rs -	Rs 2,880,000	Rs 4,800,000
Utility Service Cost (per site) [PKR]	Rs 104,000	Rs 1,040,000	Rs 1,040,000
Total number of chargers [#]	2	3	5
Total number of stations [#]	1	1	1
Total initial Charging Station Capital Required [PKR]	**Rs 29,602,000**	**Rs 20,684,000**	**Rs 1,240,000**
Annual depreciation [PKR]	**Rs 2,960,200**	**Rs 2,068,400**	**Rs 124,000**

Charging Station Utilization	Level 4 - 150 KW	Level 3 - 50 KW	Level 2 AC 7 KW
Utilization Rate	20%	20%	40%
Maximum number of charging sessions per station [sessions/year/station]	26,280	17,520	4,380
Energy Usage			
Average charging energy per session [kWh/session]	50	25	14
Maximum power draw [kW/session]	150	50	7
Average time of charging session (minutes)	20	30	120
Optimized Charging			
Peak Sessions	30%	30%	30%
Off-Peak Session	70%	70%	70%

Charging Station Revenue [Operating Revenue - Direct]	Revenue Model Applies?	Level 4 - 150 KW	Level 3 - 50 KW	Level 2 AC 7 KW
Per-energy user fee (Peak) [PKR/kWh]	Y	Rs 33	Rs 50	Rs 29
Per-energy revenue (Peak)				
Per-energy user fee (Off-peak) [PKR/kWh]		Rs 28	Rs 45	Rs 24
Per-energy revenue (Off-Peak)				
Per-charge event user fee (Off-Peak) [PKR/session]	N	Rs 5	Rs 5	Rs 5
Per-charge event revenue				

Operating Cost Assumptions	Level 4 - 150 KW	Level 3 - 50 KW	Level 2 AC 7 KW
Charging Station Operating Cost [Cost of Sales]			
Electricity			
Electricity retail price in first year Peak [PKR/kWh]	Rs 20	Rs 20	Rs 20
Electricity retail price in first year Off Peak [PKR/kWh]	Rs 15	Rs 15	Rs 15
Annual compounded growth rate in electricity price [%]	0.10%	0.10%	0.10%
Demand charge [PKR/kW/month]	Rs -	Rs -	Rs -
Maintenance cost			
Annual maintenance cost as percentage of equipment value [%]	5%	5%	5%
Maintenance cost (annual)			
Host site lease or access cost			
Host site lease or access cost (average per site/year) [PKR]	Rs 600,000	Rs 600,000	Rs 500,000
Host site lease or access cost (annual)			
Additional Operating Costs			
Sales, General, and Administrative [% of Revenue]	5%	5%	5%
Income Tax	0%	0%	5%

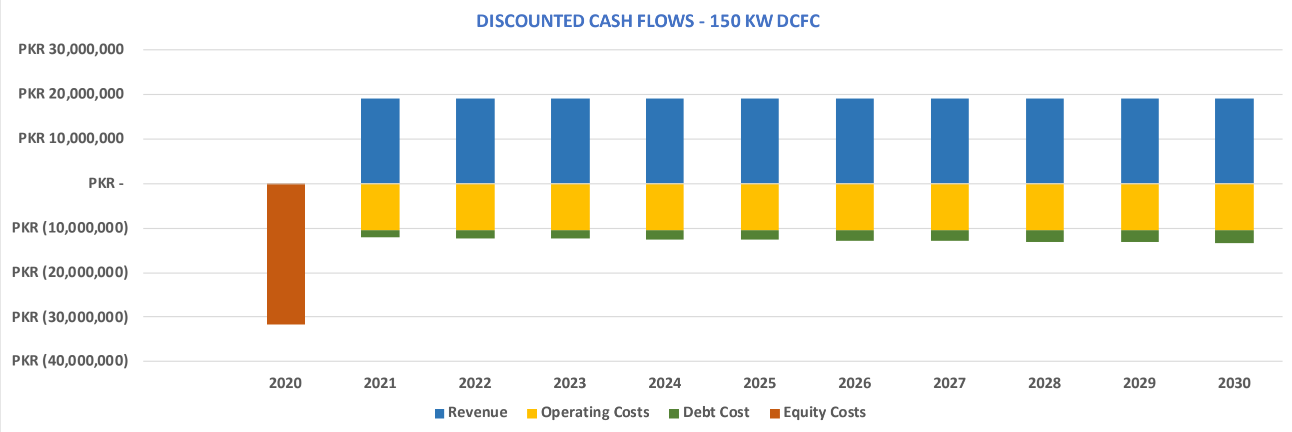
Initial Capitalization Assumptions		Level 4 - 150 KW		Level 3 - 50 KW		Level 2 AC 7 KW	
Initial Property, Plant, and Equipment		Rs	29,602,000	Rs	20,684,000	Rs	1,240,000
Initial Operating Capital [2x SG&A]		Rs	1,534,752	Rs	1,222,020	Rs	309,911
Total Initial Capital Required		Rs	31,136,752	Rs	21,906,020	Rs	1,549,911
Percent Equity Funded [%]	30%	Rs	9,341,026	Rs	6,571,806	Rs	464,973
Percent Debt Funded [%]	70%	Rs	21,795,726	Rs	15,334,214	Rs	1,084,938
Total Funded		Rs	31,136,752	Rs	21,906,020	Rs	1,549,911
Interest Rate			**6%**		**6%**		**6%**
Owner Operator Cost of Equity							
Risk Free Rate			1.38%		1.38%		1.38%
Beta			1		1		1
Market Risk Premium			5.00%		5.00%		5.00%
Cost of Equity			**7.96%**		**7.96%**		**7.96%**
Maximum Debt Term [years]			10		10		10
Cost of Debt (Long Term)	6.00%		6%		6%		6%
Weighted Average Cost of Capital (WACC)			**6.4%**		**6.6%**		**6.6%**

Annex - IV Discounted Cash Flow Model Outputs

Financial Performance Summary – Level 4 DCFC 150 KW Ultrafast Charger

DCFC - 150 KW Ultra Fast Charger - Motorways/Highways Discounted Cash Flow Model

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Revenue		Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400
Operating Costs		Rs (10,458,680)	Rs (10,461,834)	Rs (10,464,990)	Rs (10,468,150)	Rs (10,471,313)	Rs (10,474,480)	Rs (10,477,649)	Rs (10,480,822)	Rs (10,483,997)	Rs (10,487,176)
Debt Cost		Rs (1,673,974)	Rs (1,774,412)	Rs (1,880,877)	Rs (1,993,730)	Rs (2,113,354)	Rs (2,240,155)	Rs (2,374,564)	Rs (2,517,038)	Rs (2,668,060)	Rs (2,828,144)
Equity Costs	Rs (31,520,440)	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -
Total	Rs (31,520,440)	Rs 7,051,746	Rs 6,948,154	Rs 6,838,532	Rs 6,722,520	Rs 6,599,733	Rs 6,469,766	Rs 6,332,187	Rs 6,186,541	Rs 6,032,342	Rs 5,869,080



Financial Performance Summary

Capital Investment	Rs	31,520,440
Equity	Rs	9,456,132
Debt	Rs	22,064,308
Net Present Value	Rs	27,024,503
Internal Rate of Return (IRR)		15.3%
Discounted Payback (Years)		5.00
Number of Charging Sessions Provided [#]		105,120
Electricity Sold [MWh]		5,256
GHG Emissions Abated (CO2e tons)		
Charging Station Utilization		20%
Charging Station Operator Profit Margin [PKR/kWh]	Rs	20.0
Electricity Retail Price - Peak Hours [PKR/kWH]	Rs	20.0
Electricity Sale Price - Peak Hours [PKR/kWH]	Rs	40.0
Electricity Retail Price - Off Peak Hours [PKR/kWH]	Rs	15.0
Electricity Sale Price - Off Peak Hours [PKR/kWH]	Rs	35.0
Levelized Cost to the End Consumer [PKR/kWh]	Rs	36.5

Discounted Cash Flows – Level 4 DCFC 150 KW Ultrafast Charger

DC FAST 150 KW CHARGING STATION

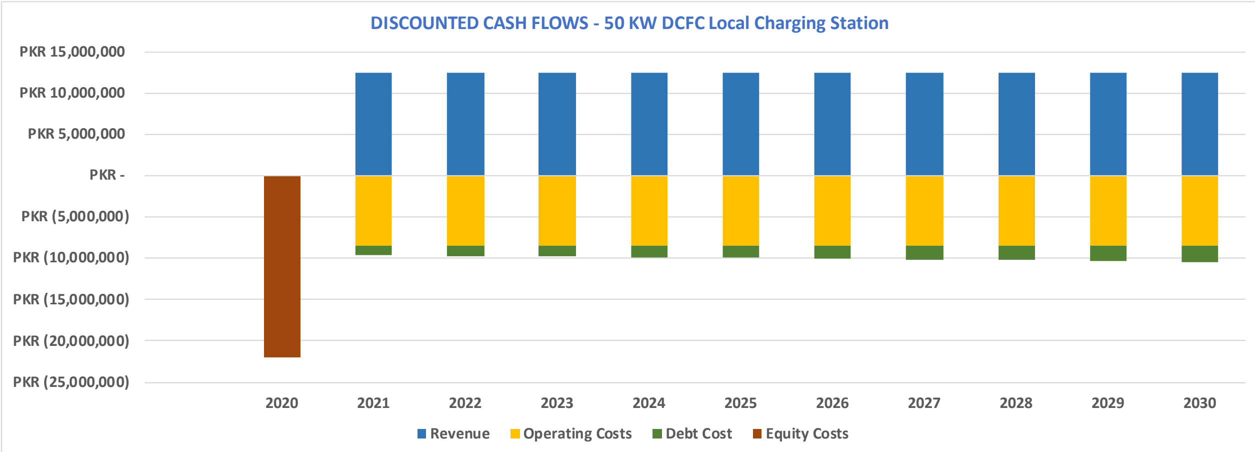
Discounted Cash Flow Model		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		0	1	2	3	4	5	6	7	8	9	10
Revenue			Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400	Rs 19,184,400
Operating Costs			Rs (10,458,680)	Rs (10,461,834)	Rs (10,464,990)	Rs (10,468,150)	Rs (10,471,313)	Rs (10,474,480)	Rs (10,477,649)	Rs (10,480,822)	Rs (10,483,997)	Rs (10,487,176)
EBITDA			Rs 8,725,720	Rs 8,722,566	Rs 8,719,410	Rs 8,716,250	Rs 8,713,087	Rs 8,709,920	Rs 8,706,751	Rs 8,703,578	Rs 8,700,403	Rs 8,697,224
Dep & Amortization			Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)	Rs (2,960,200)
Operating Income (EBIT)			Rs 5,765,520	Rs 5,762,366	Rs 5,759,210	Rs 5,756,050	Rs 5,752,887	Rs 5,749,720	Rs 5,746,551	Rs 5,743,378	Rs 5,740,203	Rs 5,737,024
Interest Expense			Rs (1,323,858)	Rs (1,223,420)	Rs (1,116,955)	Rs (1,004,103)	Rs (884,479)	Rs (757,678)	Rs (623,268)	Rs (480,795)	Rs (329,772)	Rs (169,689)
Income Before Taxes (EBT)			Rs 4,441,662	Rs 4,538,946	Rs 4,642,254	Rs 4,751,947	Rs 4,868,408	Rs 4,992,043	Rs 5,123,283	Rs 5,262,584	Rs 5,410,430	Rs 5,567,335
Taxes			Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -
Cash Flow from Operations			Rs 7,401,862	Rs 7,499,146	Rs 7,602,454	Rs 7,712,147	Rs 7,828,608	Rs 7,952,243	Rs 8,083,483	Rs 8,222,784	Rs 8,370,630	Rs 8,527,535
Free Cash Flow to Equity			Rs 7,401,862	Rs 7,499,146	Rs 7,602,454	Rs 7,712,147	Rs 7,828,608	Rs 7,952,243	Rs 8,083,483	Rs 8,222,784	Rs 8,370,630	Rs 8,527,535
Terminal Value												
Total Free Cash Flow		**-Rs29,602,000**	**Rs7,401,862**	**Rs7,499,146**	**Rs7,602,454**	**Rs7,712,147**	**Rs7,828,608**	**Rs7,952,243**	**Rs8,083,483**	**Rs8,222,784**	**Rs8,370,630**	**Rs8,527,535**
Discount Factor	6.4%	1.000	0.939	0.883	0.829	0.779	0.732	0.687	0.646	0.607	0.570	0.535
Discounted Cash Flows		-Rs29,602,000	Rs6,953,714	Rs6,618,561	Rs6,303,496	Rs6,007,293	Rs5,728,803	Rs5,466,947	Rs5,220,711	Rs4,989,142	Rs4,771,348	Rs4,566,488
Cumulative Discounted Cash Flows		**-Rs29,602,000**	**-Rs22,648,286**	**-Rs16,029,725**	**-Rs9,726,229**	**-Rs3,718,936**	**Rs2,009,867**	**Rs7,476,814**	**Rs12,697,525**	**Rs17,686,667**	**Rs22,458,015**	**Rs27,024,503**

Net Present Value	**Rs27,024,503**
Internal Rate of Return	**15.3%**
Discounted Payback	**5.0**

Financial Performance Summary – Level 3 DCFC 50 KW Fast Charger

DCFC - 50 KW - Local Charging Station - Discounted Cash Flow Model

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Revenue		Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000
Operating Costs		Rs (8,453,750)	Rs (8,455,327)	Rs (8,456,905)	Rs (8,458,485)	Rs (8,460,067)	Rs (8,461,650)	Rs (8,463,234)	Rs (8,464,821)	Rs (8,466,409)	Rs (8,467,998)
Debt Cost		Rs (1,164,771)	Rs (1,234,657)	Rs (1,308,737)	Rs (1,387,261)	Rs (1,470,497)	Rs (1,558,727)	Rs (1,652,250)	Rs (1,751,385)	Rs (1,856,468)	Rs (1,967,856)
Equity Costs	Rs (21,932,300)	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -
Total	Rs (21,932,300)	Rs 2,864,479	Rs 2,793,016	Rs 2,717,358	Rs 2,637,254	Rs 2,552,437	Rs 2,462,624	Rs 2,367,515	Rs 2,266,794	Rs 2,160,123	Rs 2,047,146



Financial Performance Summary

Capital Investment	Rs	21,932,300
Equity	Rs	6,579,690
Debt	Rs	15,352,610
Net Present Value	Rs	18,652,650
Internal Rate of Return (IRR)		15.2%
Discounted Payback (Years)		5.00
Number of Charging Sessions Provided [#]		105,120
Electricity Sold [MWh]		2,628
GHG Emissions Abated (CO2e tons)		
Charging Station Utilization		20%
Charging Station Operator Profit Margin [PKR/kWh]		31.00
Electricity Retail Price - Peak Hours [PKR/kWH]		20.00
Electricity Sale Price - Peak Hours [PKR/kWH]		51.00
Electricity Retail Price - Off Peak Hours [PKR/kWH]		15.00
Electricity Sale Price - Off Peak Hours [PKR/kWH]		46.00
Levelized Cost to the End Consumer [PKR/kWh]		47.50

Discounted Cash Flows – Level 3 DCFC 50 KW Ultrafast Charger

DC FAST 50 KW CHARGING STATION

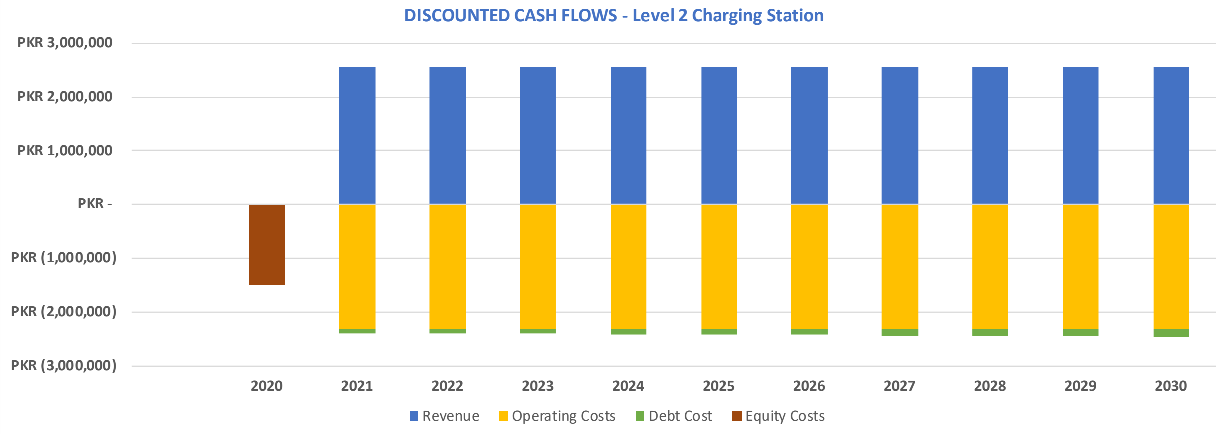
Discounted Cash Flow Model		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		0	1	2	3	4	5	6	7	8	9	10
Revenue			Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000	Rs 12,483,000
Operating Costs			Rs (6,385,350)	Rs (6,386,927)	Rs (6,388,505)	Rs (6,390,085)	Rs (6,391,667)	Rs (6,393,250)	Rs (6,394,834)	Rs (6,396,421)	Rs (6,398,009)	Rs (6,399,598)
EBITDA			Rs 6,097,650	Rs 6,096,073	Rs 6,094,495	Rs 6,092,915	Rs 6,091,333	Rs 6,089,750	Rs 6,088,166	Rs 6,086,579	Rs 6,084,991	Rs 6,083,402
Dep & Amortization			Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)	Rs (2,068,400)
Operating Income (EBIT)			Rs 4,029,250	Rs 4,027,673	Rs 4,026,095	Rs 4,024,515	Rs 4,022,933	Rs 4,021,350	Rs 4,019,766	Rs 4,018,179	Rs 4,016,591	Rs 4,015,002
Interest Expense			Rs (921,157)	Rs (851,270)	Rs (777,191)	Rs (698,667)	Rs (615,431)	Rs (527,201)	Rs (433,678)	Rs (334,543)	Rs (229,459)	Rs (118,071)
Income Before Taxes (EBT)			Rs 3,108,093	Rs 3,176,403	Rs 3,248,904	Rs 3,325,848	Rs 3,407,502	Rs 3,494,149	Rs 3,586,088	Rs 3,683,637	Rs 3,787,132	Rs 3,896,931
Taxes			Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -
Cash Flow from Operations			Rs 5,176,493	Rs 5,244,803	Rs 5,317,304	Rs 5,394,248	Rs 5,475,902	Rs 5,562,549	Rs 5,654,488	Rs 5,752,037	Rs 5,855,532	Rs 5,965,331
Free Cash Flow to Equity			Rs 5,176,493	Rs 5,244,803	Rs 5,317,304	Rs 5,394,248	Rs 5,475,902	Rs 5,562,549	Rs 5,654,488	Rs 5,752,037	Rs 5,855,532	Rs 5,965,331
Terminal Value												Rs -
Total Free Cash Flow		-Rs20,684,000	Rs5,176,493	Rs5,244,803	Rs5,317,304	Rs5,394,248	Rs5,475,902	Rs5,562,549	Rs5,654,488	Rs5,752,037	Rs5,855,532	Rs 5,965,331
Discount Factor	6.59%	1.000	0.938	0.880	0.826	0.775	0.727	0.682	0.640	0.600	0.563	0.528
Discounted Cash Flows		**-Rs20,684,000**	**Rs4,856,544**	**Rs4,616,497**	**Rs4,391,031**	**Rs4,179,243**	**Rs3,980,285**	**Rs3,793,359**	**Rs3,617,721**	**Rs3,452,671**	**Rs3,297,551**	**Rs3,151,747**
Cumulative Discounted Cash Flows		**-Rs20,684,000**	**-Rs15,827,456**	**-Rs11,210,959**	**-Rs6,819,927**	**-Rs2,640,684**	**Rs1,339,601**	**Rs5,132,960**	**Rs8,750,681**	**Rs12,203,352**	**Rs15,500,903**	**Rs18,652,650**

Net Present Value	**Rs 18,652,650**
Internal Rate of Return	**15.2%**
Discounted Payback	**5.00**

Financial Performance Summary – Level 2 AC 7 KW Charger

Level 2 Charging Station - 7 KW

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Revenue		Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242
Operating Costs		Rs (2,317,982)	Rs (2,318,534)	Rs (2,319,086)	Rs (2,319,639)	Rs (2,320,193)	Rs (2,320,747)	Rs (2,321,302)	Rs (2,321,857)	Rs (2,322,413)	Rs (2,322,969)
Debt Cost		Rs (79,482)	Rs (84,251)	Rs (89,306)	Rs (94,664)	Rs (100,344)	Rs (106,365)	Rs (112,747)	Rs (119,512)	Rs (126,682)	Rs (134,283)
Equity Costs	Rs (1,496,624)		Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -
Total	Rs (1.496.624)	Rs 168.778	Rs 163.457	Rs 157.850	Rs 151.938	Rs 145.705	Rs 139.130	Rs 132.193	Rs 124.873	Rs 117.147	Rs 108,990



Financial Performance Summary

Capital Investment	Rs 1,496,624
Equity	Rs 448,987
Debt	Rs 1,047,637
Net Present Value	Rs 1,117,767
Internal Rate of Return (IRR)	15.1%
Discounted Payback (Years)	5.00
Number of Charging Sessions Provided [#]	65,700
Electricity Sold [MWh]	920
GHG Emissions Abated (CO2e tons)	
Charging Station Utilization	30%
Charging Station Operator Profit Margin [PKR/kWh]	Rs 11.4
Electricity Retail Price - Peak Hours [PKR/kWH]	Rs 20.0
Electricity Sale Price - Peak Hours [PKR/kWH]	Rs 31.4
Electricity Retail Price - Off Peak Hours [PKR/kWH]	Rs 15.0
Electricity Sale Price - Off Peak Hours [PKR/kWH]	Rs 26.4
Levelized Cost to the End Consumer [PKR/kWh]	Rs 27.9

Discounted Cash Flows – Level 2 AC 7 KW Charger

Level 2 AC Charging

Discounted Cash Flow Model		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		0	1	2	3	4	5	6	7	8	9	10
Revenue			Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242	Rs 2,566,242
Operating Costs			Rs (2,193,982)	Rs (2,194,534)	Rs (2,195,086)	Rs (2,195,639)	Rs (2,196,193)	Rs (2,196,747)	Rs (2,197,302)	Rs (2,197,857)	Rs (2,198,413)	Rs (2,198,969)
EBITDA			Rs 372,260	Rs 371,708	Rs 371,156	Rs 370,603	Rs 370,049	Rs 369,495	Rs 368,940	Rs 368,385	Rs 367,829	Rs 367,273
Dep & Amortization			Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)	Rs (124,000)
Operating Income (EBIT)			Rs 248,260	Rs 247,708	Rs 247,156	Rs 246,603	Rs 246,049	Rs 245,495	Rs 244,940	Rs 244,385	Rs 243,829	Rs 243,273
Interest Expense			Rs (62,858)	Rs (58,089)	Rs (53,034)	Rs (47,676)	Rs (41,996)	Rs (35,975)	Rs (29,593)	Rs (22,829)	Rs (15,658)	Rs (8,057)
Income Before Taxes (EBT)			Rs 185,402	Rs 189,619	Rs 194,121	Rs 198,927	Rs 204,053	Rs 209,520	Rs 215,347	Rs 221,556	Rs 228,171	Rs 235,216
Taxes			Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -	Rs -
Cash Flow from Operations			Rs 309,402	Rs 313,619	Rs 318,121	Rs 322,927	Rs 328,053	Rs 333,520	Rs 339,347	Rs 345,556	Rs 352,171	Rs 359,216
Free Cash Flow to Equity			Rs 309,402	Rs 313,619	Rs 318,121	Rs 322,927	Rs 328,053	Rs 333,520	Rs 339,347	Rs 345,556	Rs 352,171	Rs 359,216
Total Free Cash Flow		Rs (1,240,000)	Rs 309,402	Rs 313,619	Rs 318,121	Rs 322,927	Rs 328,053	Rs 333,520	Rs 339,347	Rs 345,556	Rs 352,171	Rs 359,216
Discount Factor	6.59%	1.000	0.938	0.880	0.826	0.775	0.727	0.682	0.640	0.600	0.563	0.528
Discounted Cash Flows		**Rs (1,240,000)**	**Rs 290,278**	**Rs 276,048**	**Rs 262,705**	**Rs 250,190**	**Rs 238,453**	**Rs 227,442**	**Rs 217,113**	**Rs 207,421**	**Rs 198,326**	**Rs 189,790**
Cumulative Discounted Cash Flows		**Rs (1,240,000)**	**Rs (949,722)**	**Rs (673,673)**	**Rs (410,969)**	**Rs (160,778)**	**Rs 77,675**	**Rs 305,117**	**Rs 522,230**	**Rs 729,651**	**Rs 927,977**	**Rs 1,117,767**

Net Present Value	**Rs 1,117,767**
Internal Rate of Return	15.1%
Discounted Payback	5.00

Annex – V Hardware Cost of Charging Infrastructure

Although EV charging technology has been standardized around the world, but the installation costs vary widely even within the region. Electric vehicle chargers generally require significant site preparation for electrical infrastructure. For this reason, charging hardware represents only a portion of costs, and the total cost of installing charging stations vary substantially depending on the site. Because of these variances, such as labor costs, specific infrastructure needs along with charging hardware and materials, EV charging station costs must be assessed on a site by site basis. Table A and B below provide hardware cost estimates for EV charging stations for various regional markets.

Table A: AC Chargers installation costs at several regional markets. Source: Economic Research Institute for ASEAN and East Asia

AC Charging Infrastructure – Hardware Costs

Countries (Currency)	Application	Costs	Included Items
United States (US$)	L2 – home	450–1,000 (50–100)	Charging station hardware (additional electrical material costs in parentheses)
	L2 – parking garage	1,500–2,500 (210–510)	
	L2 – curb side	1,500–3,000 (150–300)	
France, Germany, Italy, Netherlands, Spain, UK (euro)	3.7 kW new residential building	1,170	Materials (for installation, including cables); wall-box (hardware of charging station, excluding cables); and labour (around 20% of total costs)
	3.7 kW operating residential building	1,280	
	7.4 kW new nonresidential building	1,760	
	7.4 kW operating nonresidential building	2,025	
Germany (euro)	>3.7 kW – one charging point	1,200	Complete hardware, including communication and smart meter
	11 kW or 22 kW – two charging points	5,000	
India (US$)	Bharat charger AC 001-1 point(s)-3 phase 415 volt-3 x 3.3 kW	980	Approximate cost, including goods and services tax at 18%
	Type-2 AC Charger-1 point(s)-22 kW	1700	
	CCS-2-1 point(s)-3 phase 415 volt-25 kW	9,800	
European Union 28 average (euro)	AC mode 2 – home (up to 11 kW)	< 800	Purchase cost for a single charging point, not installation, grid connection, or operational costs
	AC mode 2 – commercial (up to 19.4 kW)	< 2,000	
	AC mode 3 – fast (22 kW of 43 kW)	1,000 – 4,000	

DC Fast-Charging - Hardware Costs

Note: In addition to purchase cost, one needs to consider other essential costs that includes grid connection cost, civil works, software integration etc. ABB Pakistan has deployed fast charging points in several locations in Pakistan. In addition to purchase cost of charger, ABB Pakistan reports 1 Million PKR in civil works and 2 Million PKR for grid connection cost, including the transformers.

Countries (Currency)	Application	Costs	Included items
United States (US$)	DC fast charging	12,000–35,000 (300–600)	Charge station hardware (plus extra electrical materials)
Germany (euro)	50 kW	25,000	Complete hardware, including communication and smart meter
India (US$)	50 KW	20,000	Purchase cost for a single charging point, not installation, grid connection, or operational costs
European Union 28 average (euro)	DC fast – standard (20 kW–50 kW)	20,000	Purchase cost – Grasen Technologies (installation, grid connection, or operational costs not included)
	DC high power – fast (100 kW–400 kW)	40,000–60,000	
China (US$)	60 KW DC Power (CCS2 + CHAdeMO)	12,000	Purchase cost – Grasen Technologies (installation, grid connection, or operational costs not included)
	60 KW DC Power (CCS2 + CHAdeMO)	13,000	Purchase Cost – LinkCharging (installation, grid connection, or operational costs not included)
ABB Pakistan (US$)	DC 50 KW (CCS2 + CHAdeMO + Type 2 AC)	31,000	Purchase Cost – ABB (installation, grid connection, or operational costs not included)
SZS Pakistan (US$)	60 KW DC Power (CCS2 + CHAdeMO)	18,000	Purchase cost in Pakistan – Grasen Technologies

Table B: DC fast chargers hardware costs at several regional markets. **Source:** Author's compilation and Economic Research Institute for ASEAN and East Asia

Annex – VI Assumptions for TCO Analysis

2 W Segment

Variables	Electric - Sunra Bike	Honda 125	Jolta Electric Bike JE 70	Honda CD 70
Vehicle Ex-Showroom Price (PKR)	228,000	134,900	130,000	82,900
Total Fuel Cost (PKR)	45,625	264,625	43,452	220,521
Total Maintenance Cost (PKR)	25,000	60,000	24,000	48,000
Average Running/Day (Km)	50	50	50	50
Annual Running (km)	18,250	18,250	18,250	18,250
Battery Pack Size (kWh)	1.5	-	2	-
Range (Km)	75	100	70	100
Charging Cycles (#)	800	-	800	
Fuel/Electricity Cost (PKR/Unit)	20	116	20	116
Total Cost of Ownership (PKR)	**298,625.00**	**459,525.00**	**197,452.38**	**351,420.83**
Fuel Cost/km	**0.77**	**3.56**	**0.74**	**2.94**
TCO/km	**3.27**	**5.04**	**2.16**	**3.9**

3W Segment

Variables	Sazgar Electric Rickshaw	ICE Rickshaw
Vehicle Ex-Showroom Price (PKR)	500,000	250,000
Total Fuel Cost (PKR)	243,333	846,800
Total Maintenance Cost (PKR)	30,000	120,000
Salvage Value (PKR)	-	-
Additional Battery Cost (PKR)	-	-
Average Running/Day (Km)	100	100
Annual Running	30,000	30,000
Battery Pack Size (kWh)	7.7	-
Range (Km)	170	100
Charging Cycles (#)	800	-
Fuel or Electricity Cost (Rs/Unit)	20	116
Total Cost of Ownership (PKR)	**773,333.33**	**1,216,800.00**
Fuel Cost/km (PKR)	**1.50**	**5.30**
Cost/KM (PKR)	**4.2**	**6.7**

4W Segment

Variables	MG ZS EV	MG HS	Audi e-tron 50 quattro	Mercedes Benz GLA Class 200	Hyundai Ioniq Electric	Honda Civic - Turbo 1.5
Vehicle Ex-Showroom Price (PKR)	6,000,000	5,500,000	16,750,000	13,500,000	6,569,212	4,846,104
Total Fuel Cost (PKR)	254,237	1,087,500	300,000	1,087,500	214,286	966,667
Total Maintenance Cost (PKR)	30,000	180,000	30,000	180,000	30,000	180,000
Salvage Value (PKR)		-		-		-
Additional Battery Cost (PKR)		-		-		-
Average Running/Day (Km)	50	50	50	50	50	50
Annual Running	15,000	15,000	15,000	15,000	15,000	15,000
Battery Pack Size (kWh)	44.4	-	65	-	38	-
Range (Km)	250	640	280	600	250	600
Charging Cycles (#)	2,000	-	2,000	-	2,000	-
Fuel or Electricity Cost (Rs/Unit)	20	116	20	116	20	116
Total Cost of Ownership (PKR)	**6,284,237.29**	**6,767,500.00**	**17,080,000.00**	**14,767,500.00**	**6,813,497.71**	**5,992,770.67**
Running Cost/km (PKR)	**3.8**	**16.9**	**4.40**	**16.9**	**3.3**	**15**
Total Cost/KM (PKR)	**84**	**90**	**228**	**197**	**91**	**80**

Bus Segment

Variables	Electric Bus - 12 M	Diesel Bus - 12 M
Vehicle Ex-Showroom Price (PKR)	35,000,000	20,000,000
Total Fuel Cost (PKR)	17,884,615	44,562,500
Total Maintenance Cost (PKR)	240,000	1,800,000
Salvage Value (PKR)	-	-
BatteryReplacement Cost (PKR)	6,739,200	-
Time period (Years)	10	10
Average Running/Day (Km)	250	250
Battery Pack Size (kWh)	324.0	-
Range (km)	250	600
Charging Cycles (#)	2,000	
Fuel or Electricity Cost (Rs/Unit)	20	115
Additional Battery (#)	1	-
Total Cost of Ownership (PKR)	**59,863,815**	**66,362,500**
TCO (PKR/km)	**77**	**86**
Fuel Cost	**32**	**60**