Action Plan for Electricity Utilities of SAARC Countries to Introduce EV Charging Infrastructure

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Foreword

The conventional Internal Combustion Engine (ICE) vehicles form the backbone of the transport sector. However, these vehicles are also responsible for high levels of air pollution, leading to major health concerns. In the SAARC region, the vehicular emissions have been identified as the primary sources of air pollution. Therefore, introduction of Electric vehicles (EVs) is the need of the region towards sustainable transport. Electric vehicles (EVs) are gaining popularity in SAARC region due to fuel savings, lower maintenance and robust performance. This requires an adequate charging infrastructure in place to support the uptake of the EVs in region. The electric utility companies are also concerned over the deployment of the charging infrastructure as it requires an integrated planning and robust action plan to support the growing needs of EVs market.

In this context, SAARC Energy Centre (SEC), conducted this study to draft an action plan for electric utility supply companies of SAARC Member States to introduce the EV charging infrastructure. The study assessed the EV market in three SAARC Member States, namely Bhutan, India and Pakistan, and devised an action plan for selected electric utility in each of the three countries to deploy EV charging infrastructure. A market readiness assessment was conducted for these three Member States by looking at the policy level, industry level and end-user level interest in the EV segment. Overall EV sales were also studied and projections were made for the next 10 years (till 2030) by benchmarking to major underliers such as rise in consumer interest, change in EV economics and effectiveness of policies governing e-mobility. The study also explores the trends in the global EV market, charging technologies and global standards for EVs charging infrastructure. In the end, viable business model was recommended for the electric utilities to enter the business of EV charging station deployment. The business model development had taken into consideration all possible facets and has been validated by selected utilities in Bhutan, India, and Pakistan.

The study findings depicts that the market preparedness and acceptance for EVs is different for the three SAARC Member States. Bhutan’s small size and mountainous terrain, make wide acceptance of EVs as personal commute questionable. India looks to be well-poised to make the EV transition in the next decade while Pakistan faces uncertainties due to weak economy. Different risks alter suitability of business models from one country to the other. The study devised an action plan in close consultation with market participants and shortlisted electric utilities, which takes into account country level risks without compromising on global uncertainties.

Dr Nawaz Ahmad Virk
Director,
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Executive Summary

This report has assessed the EV market in the three SAARC Member States (SMS), namely Bhutan, India and Pakistan, and devised an action plan for an electric utility in each of the three geographies to deploy EV charging infrastructure in their respective licensee areas. Electric utilities, which have been in the business of selling power to their customers, have a new business opportunity ahead as electricity becomes the new oil for vehicles. However, conventionally, utilities across the world (albeit exceptions) tend to take a conservative "wait and watch" approach in the initial phases of EV adoption, and due to bureaucratic structures, lack of government interest (for state-owned utilities) and unpreparedness towards changing business areas, their participation is this new business opportunity is affected. The report intends to allay some of the uncertainties of such utilities by enumerating scalable business models based on feasibility and practicability. Following are the study outcomes for the three member states:

Bhutan

The uptake of EVs in Bhutan has been slow with only ~102 EVs plying in the country and four charging stations as of June 2019. The Royal Government of Bhutan (RGoB) plans to roll out 300 EVs in the country by 2021. As per study author's estimates, population of EVs will reach ~700 by CY 2024 and ~2100 by CY 2030 majorly due to replacement of taxi fleet in cities, tax incentives/ tax rebates given out by the government and rise in fossil fuel prices.

The study authors have worked with Bhutan Power Corporation Ltd. (BPC) which is the only power distribution utility in the country. Based on two different scenarios of low EV and high EV uptake in the country, it is estimated that ~47 and ~104 charging stations would be required by 2030 respectively. This entails capital investment required is Nu 101,333,895 (US$ 1,447,627) for low uptake and Nu 190,522,472 (US$ 2,721,749) for high uptake. Furthermore, an OPEX (operating expense) requirement of Nu 16,071,677 (US$ 229,595) and Nu 16,262,046 (US$ 232,315) for low and high uptake respectively would be necessitated.

Financial viability studies of a Public Charging System (PCS) in Bhutan shows that at least 77.5% station utilisation levels is required for electricity selling price of Nu 7/ kWh, which reduces mildly to ~68% for electricity selling price of Nu 7.5/ kWh. This shows that station utilisation levels need to be high enough to cover front leaded capital expenditure (CAPEX) costs.

Based on discussions with BPC and market participants, four business models have been highlighted:

Table 1: Summary of Business Models for EV Charging Stations in Bhutan

Initial Investment	Operation & Maintenance	Risk
Government	Government	Unsustainable
Government	Government	Unsustainable
Government	Private company/BPC	Low
BPC alone or through PPP	BPC alone or through PPP	Risky

The third business model is found to be the most sustainable model. Here, the government takes the responsibility to install Electric Vehicle Charging Station (EVCS) and leases out to a private company or BPC to manage, operate and maintain for a fixed term with a condition that at the end of the lease period the lessee has to restore the EVCS to its original condition. Here, the government does not have any risk and will also be able to recover the investment at the end of the lease period. Similarly, it will be a good opportunity for BPC to enter into the e-mobility space without adopting the associated risks and uncertainties in its entirety.

India

While there are close to 1.7 million EVs in the country (with majority being e-rickshaws), the same is expected to reach ~80.4 million by fiscal 2030. This is led by conducive economics (total cost of ownership benefits), declining battery prices, subsidy support from government and development of a strong enabling ecosystem (charging station development, domestic EV manufacturing). The exponential rise in EVs, albeit majorly in the two wheeler (2W) and three wheeler (3W) segments (which charge at home/ office), needs to be supplemented by adequate PCS deployment.

A benchmarking study was carried out in which all major electric utilities in the country were assessed on major financial and operational parameters to assess the readiness of utilities for setting up PCS infrastructure in their respective licensee areas. Post the benchmarking study author has worked with BSES Yamuna Private Limited (BYPL), a private utility supplying power to Eastern and Central Delhi.

As per estimates, the requirement of additional load in lieu of EV charging will reach ~250-gigawatt hour (GWh) in fiscal 2024 and ~750 GWh in fiscal 2030. This effect can be alleviated by distribution network planning and effective ToU implementation. Based on model of location planning for charging station deployment, each of BYPL's fourteen (14) circles were studied closely in consultation with the senior leadership of the utility on several parameters. Six out of 14 divisions were found to be suitable for charging station deployment. Furthermore, financial viability of PCS was assessed based on two underliers/ risks: delivered cost of power and station utilisation. It was found that a PCS with fast chargers will not be viable in today's time due to high upfront charger costs and potential stranded costs (owing to non-utilisation).

In fact, for a PCS of 6 chargers (3 fast chargers and 3 slow chargers), a federal subsidy of ~65%-70% on Electric Vehicle Supply Equipment (EVSE) would be required for breaking even in 5 years. However, economics are expected to be more conducive as EV sales grow and market matures, thereby bringing down charger costs and improving station utilisation.

The summary of business models as proposed are as follows:

Table 2: Summary of Business Models for EV Charging Stations in India

Business Model	Modalities	Risk
Make-ready	The utility invests in 'make-ready' installations by providing electrical infrastructure	Minimal
Rebates for EVSEs	Utilities provide host sites with financial incentives	Moderate
Public-private partnerships (PPP)	Both entities cover a portion of the infrastructure cost, as mutually agreed, through a joint venture or a special purpose vehicle	Moderate
Owner and operator	The utility engages in electric grid enhancements and upgrades as well as full build-out and operation of EVSEs at host sites.	High

The electric utility, based on market conditions and viability, has been advised to set up PCS, either through the PPP mode or by making strategic investments in make-ready installations in phase 1 (fiscals 2020-2024). Locations with early EV adopters needs to be tapped to avoid low usage. In phase 2 (fiscals 2025-2030), as battery technologies mature, the owner-operator route may be explored in strategic locations while keeping the PPP model as the main stay.

Pakistan

While the population of full-fledged electric vehicles in the country is miniscule, that of the hybrid cars imported into Pakistan has risen steadily. As of June 2019, a total of 250 plug-in hybrids and full EVs were registered in Pakistan, with 90% being plug-in hybrid cars. As per estimates by study authors, electric cars density by 2030 is expected to be 15%, i.e., four electric cars per 1000 people with close to 1 million EVs on the roads cumulatively during the same time. This will be led by government push, policy incentives and rise in per capita income in the country.

Post financial benchmarking of electric utilities, the study authors worked with Islamabad Electric Supply Company (IESCO), a state utility supplying power to Islamabad region and to districts of Rawalpindi, Jhelum, Attock and Chakwal. Based on market interactions and discussions with the leadership team of IESCO, a total of 46 potential charging station locations have been identified, with 23 in Phase 1 (CY 2020 – 2025) and the rest in phase 2 (CY 2026 - 2030). Based on the same, the utility has laid out plans for upgradation of its power systems, totalling ~44,256 million PKR till 2030, with Distribution System Expansion (DOP) entailing ~ 12,294 million PKR. The proposed business models for entering the EV charging station deployment are as follows:

Table 3: Summary of Business Models for EV Charging Stations in Pakistan

Business Model	Modalities	Risk
Public Private Partnership	Long-term contract (~15 years) between the public party and the private party, for the development and management of PCS, with proposed equity share between public and private parties of 70% and 30%, respectively	High
Build operate transfer (BOT)	The public party delegates to a private sector entity to design and build infrastructure and to operate as well as maintain these facilities for a certain concession period	Low

Based on practicality and feasibility, it is suggested that IESCO invest in make-ready PCS installations by setting up necessary distribution networks, transformers, meters and other electrical equipment. The charger costs and other EVSE will be set up by interested private parties. The O&M of the sites will be the responsibility of the host of the EV chargers, where the maintenance can be sublet to service companies and these costs can be incorporated in the tariff models. The total CAPEX required by IESCO to invest in ready-to-build sites for the period of next 10 years will be approximately 70.4 million PKR. Delivering power to ready-to-build sites is a more practical approach to give a push-start for setting up charging infrastructure in the licensee area. This will shield the electric utility from unwanted risks and uncertainties in the EV space.

Overall, it is observed that the market preparedness and acceptance for EVs is different for the three SMS. While India looks to be well-poised to make the EV transition in the next decade, uncertainties hog Pakistan due to lack of federal policy and weak economy. Bhutan’s small size and mountainous terrain, on the other hand, make wide acceptance of EVs as personal commute questionable. Different risks alter suitability of business models from one geography to the other. The models, devised in close consultation with market participants and shortlisted electric utility, take into account country level risks without compromising on global uncertainties.

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Abbreviations

ARAI	Automotive Research Association of India
ACS	Average Cost of Supply
AENS	Average Energy Not Supplied
AEV	Autonomous Electric Vehicle
BCD	Basic Customs Duty
BPC	Bhutan Power Corporation Ltd
BYPL	BSES Yamuna Power Limited
BOT	Build Operate Transfer
BIS	Bureau of Indian Standards
BRT	Bus Rapid Transit
CAPEX	Capital Expenditure
CEA	Central Electric Authority
CEB	Ceylon Electricity Board
CPPA	Central Power Purchasing Agency
CHAdeMO	Charge de Move
CPEC	China Pakistan Economic Corridor
CCS	Combined Charging System
CBU	Completely Built Unit
CAGR	Compounded Annual Growth Rate
CNG	Compressed Natural Gas
CE	Consumers Energy
CAN	Control Area Network
CAIDI	Customer Average Interruption Duration Index
CKD	Completely Knocked Down
DHI	Department of Heavy Industry
DC	Direct Charging
DISCO	Distribution Company
DMRC	Delhi Metro Railway Corporation
DT	Distribution Transformer
DGPC	Druk Green Power Corporation
DHI	Druk Holding and Investment Limited
DRE	Distributed Renewable Energy
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station

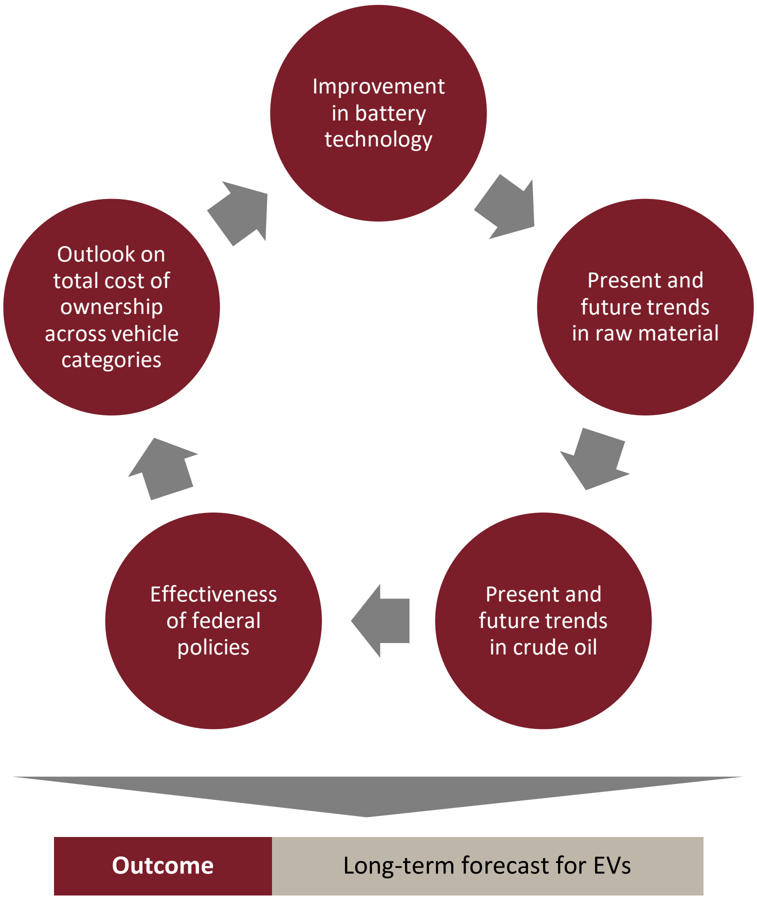
EVSE	Electric Vehicle Supply Equipment
eMIP	eMobility Inter-Operation Protocol
EESL	Energy Efficiency Services Limited
EoI	Expression of Interest
FESCO	Faisalabad Electric Supply Company
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India
FACT	Flexible Alternating Current Transmission System
GENCO	Generation Company
GEF	Global Environment Facility
GoI	Government of India
GDP	Gross Domestic Product
GEPCO	Gujranwala Electric Power Company
HEV	Hybrid Electric Vehicle
HESCO	Hyderabad Electric Supply Company
ICAT	International Centre for Automotive Technology
IEC	International Electrotechnical Committee
IEA	International Energy Agency
IESCO	Islamabad Electric Supply Company
KEL	K-Electric
LECO	Lanka Electricity Company
LESCO	Lahore Electric Supply Company
LFP	Lithium Iron Phosphate
LTO	Lithium Titanate
LT	Low Tension
LUMS	Lahore University of Management Sciences
MoU	Memorandum of Understanding
MOIC	Ministry of Information and Communication
MEPCO	Multan Electric Power Company
MHI	Ministry of Heavy Industries
NCT	National Capital Territory
NEPRA	National Electricity and Power Regulatory Authority
NTPC	National Thermal Power Corporation
NTDC	National Transmission and Dispatch Company
NPV	Net Present Value
NYPA	New York Power Authority
NMC	Nickel-manganese-cobalt
OCHP	Open Clearing House Protocol

OICP	Open Inter Change Protocol
OSCP	Open Smart Charging Protocol
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturers
OPEX	Operational Expenditure
PKR	Pakistani Rupee
PESCO	Peshawar Electric Power Company
PV	Photovoltaic
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PCS	Public Charging Station
PCT	Pakistan Customs Tariff
PPP	Public Private Partnership
PUCSL	Public Utilities Commission of Sri Lanka
QESCO	Quetta Electric Supply Company
QC	Quick Charger
RGoB	Royal Government of Bhutan
SEB	State Electricity Board
SKD	Semi Knocked Down
STU	State Transport Undertaking
SEPCO	Sukkur Electric Power Company
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
3W	Three-Wheeler
ToD	Time of Day
ToU	Time of Use
TCO	Total Cost of Ownership
TESCO	Tribal Electric Supply Company
2W	Two-Wheeler
UK	United Kingdom
UNDP	United Nations Development Programme
VG	Variable Generation
WAPDA	Water and Power Development Authority

1 Approach and Methodology

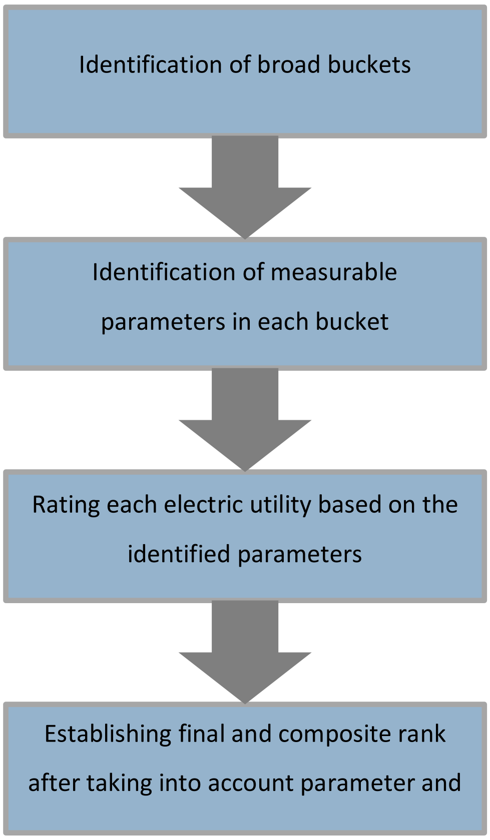
The objective of the study is to develop an action plan for a shortlisted power distribution utility in Bhutan, India and Pakistan to introduce public charging infrastructure for EVs. In order to do that, the first step is to understand the overall ecosystem of the EV market in each of the three geographies. This was done by reading up relevant country reports and speaking to stakeholders across the value chain (suppliers, original equipment manufacturers, operations, distributers, retailers, and buyers). Further, a market readiness assessment was done by looking at the policy level, industry level and end-user level interest in the EV segment. Overall EV sales were studied and projections were given for the next 10 years (till 2030) by benchmarking to major underliers such as rise in consumer interest, change in EV economics and effectiveness of federal policies governing e-mobility.

Figure 1: Methodology of Forecasting EV Sales in a Geography



In the second step, the power distribution utilities in India and Pakistan were evaluated through a financial benchmarking study to objectively shortlist one utility each from both the countries. Key parameters for utilities in India and Pakistan were collated and subsequently a utility scoring model was prepared. The scoring model has three major heads: operational metrics, financial metrics and other key parameters. Using the collated data, each utility has been rated 1/2/3/4 on each parameter based on the pre-decided rating buckets. Finally, a composite rank is assigned to the utility on the basis of a cumulative score (across three major heads). The ranking methodology of the utilities is as illustrated below:

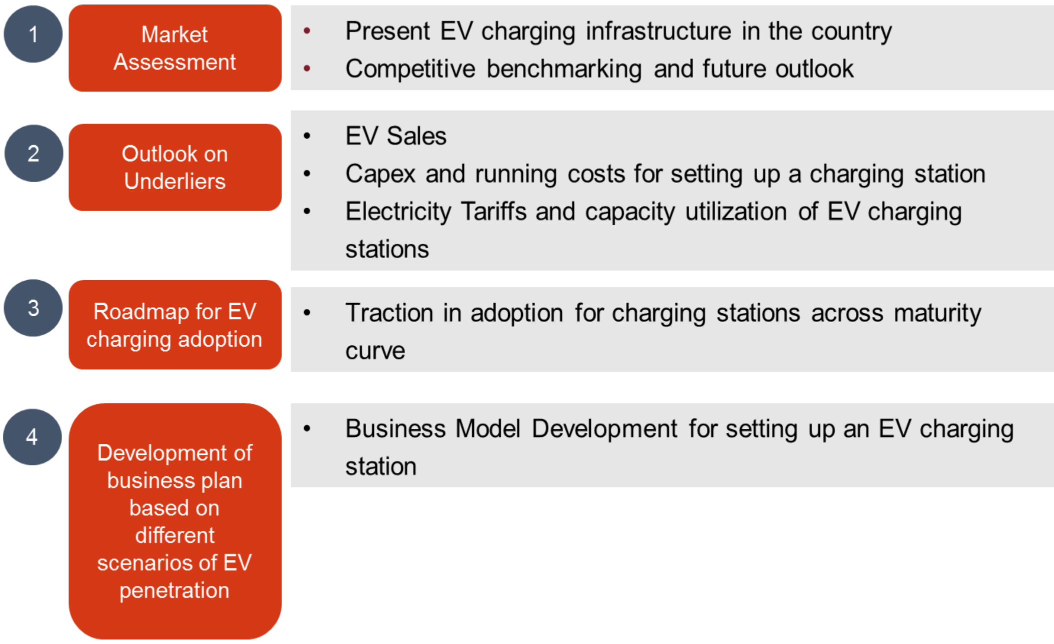
Figure 2: Methodology of Financial Benchmarking of Distribution Utilities



The benchmarking study takes into consideration major financial parameters for an electric utility such as ACS-ARR gap (difference between average cost of supply and average realizable revenue for the utility), aggregate technical and commercial (AT&C) losses, debtor and creditor positions as well as load data (industrial and commercial load, base load, peak load). Any policy or implementation framework with respect to e-mobility, if rolled out by a utility, was duly incorporated in the model.

In the third step, each of the three shortlisted utilities in India, Pakistan and Bhutan were studied in detail. This included assessment of vision/ mission of the utility, organisational structure, financial and technical capacity and existing plans for EV/e-mobility. In order to understand the preparedness and capacity of the utilities for introducing EV charging infrastructure, detailed discussions with the companies' leadership were held. In the fourth step, a market assessment of the EV charging ecosystem in the three geographies was undertaken to understand the external environment. This would preclude devising a business model for the EV charging station development.

Figure 3: Approach for Market Assessment of EV Charging Stations



The fifth step was to devise a mutually-agreed business plan for the utility to enter the business of EV charging station deployment.

Table 4: Approach for Business Plan Development

Sr. no.	Area of study	Coverage
1	Charging standards and types of chargers	Detailed study of EV charging standards in the world • Technical specifications • Communication protocols
		Federal regulations on EV charging standards • Charging standards (as specified), rated voltage and current specifications • Policy clarifications awaited
		Major factors on which charger requirements depend
		Assessment of charger requirements in the country and creation of a potential roadmap for EV charger adoption
2	Requirements for grid augmentation	Finalisation of EV charging station locations and assessment of transformer loading levels in residential/ commercial feeders in close vicinity of EV charging stations
		Assessment of voltage level fluctuations and rise in peak load demand based on different scenarios of cumulative EV charging
		Devise remediation strategies taking into consideration outlook on EV charging station utilisation as well as outlook on power demand in the area

Sr. no.	Area of study	Coverage
3	Locations for setting up a charging station	Suggest locations for prospective EV charging stations based on: • Static EV population in an area • Floating EV population in an area • Charging behaviour of EV buyers
4	CAPEX requirement	Assessment of CAPEX requirement for a charging station. Major cost heads: (a) charger costs (b) new electricity connection and grid upgradation costs (c) civil works (d) EVSE management software (e) other miscellaneous equipment
		Determination of number of charging stations to be set up by the utility each year
		Determination of capital outlays each year
5	Assessment of financial viability of a charging station	Assessment of three major risks: (a) upfront costs of a charging station (b) uncertainty about station utilisation (c) role of federal, state and local government in driving the charging station's overall viability
		Devising a viability model based on (a) utilisation factor of a charging station (b) margin on electricity tariff
		Sensitivity analysis of Net Present Value (NPV) and payback period of a charging station based on underliers
6	Business models for setting up EV charging station	Analysis of the CAPEX side and revenue side interventions for the utility
		Assessment of cost recovery methods for the utility
		Benchmarking with international utilities across the world that have invested in the EV ecosystem
		Possible business models for charging stations in the country
7	Organisational capacity planning	Assessment of external factors, knowledge management programmes
		Proposal of changes in the utility at an organisational level

The business model development has taken into consideration all possible facets and has been validated by each of the three utilities in India, Pakistan and Bhutan.

2 Global EV Market: Size, Outlook and Opportunities

2.1 Evolution

The first EV was built by Dr Ferdinand Porsche for an auto race in 1896. The fruits of the industrial revolution were beginning to loom and people's rising income and available technologies pushed individuals and companies to experiment with nascent technologies with respect to newer forms of transport. At that point in time, steam was a matured and majorly-used technology in automobiles. Electric powertrains were seen in concept cars only for demonstrative purposes. Companies were beginning to consider electric cars as the third alternative for transportation (after steam and horse-powered) owing to ease of driving (no gear-changing), zero emissions and silent to drive. However, in the early 1900s, when the Ford Model T began mass production, it sounded a death knell for electric car production. A Model T in 1912 cost $650 against an EV that costed three times more at ~$1,750. Slowly, road networks began to improve and abundant reserves of crude oil were discovered. This propelled rise in combustion engines globally and contributed to the fall of EVs, at least for the next 50 years.

The oil crisis in the 1970s was the first big jolt to internal combustion cars, when supply of oil was curtailed and prices skyrocketed following an embargo against the United States by the Organization of Petroleum Exporting Countries (OPEC). This destabilised oil prices and the innate energy security of oil-procuring nations. The US Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, 1976, to support and seed-fund research and development in electric as well as hybrid vehicles. Fast-forwarding 20 years, the passage of new federal and state policies by several countries pertaining to protection of environment renewed interest among small and big automakers. Although fuel prices bottomed in the 1990s, a rising middle class and booming economies caused a psychological shift among consumers to fuel-efficient and cleaner vehicles. More and more consumers were ready to pay a premium and adopt electric cars. The market was getting ready to take the next big leap in the automotive industry.

2.2 Rise in Popularity

The Toyota Prius, launched in 1997, was the world's first mass-produced hybrid electric vehicle. It became a hit worldwide and achieved an aspirational stature among all, despite the high price. EV technologies were still in their early stages of development and battery storage (the heart of an electric car) was still to pick up. The Toyota Prius used a nickel metal hydride battery, a technology supported by the US energy department's research. In 2006, a small Silicon Valley start-up, Tesla Motors, announced that it would begin producing luxury electric sports cars. Its first completely electric car, the Roadster, debuted in 2008 and evinced immense interest among prospective buyers.

Figure 4: Difference between Hybrid and Plug-in Cars

- **All EVs, AEVs, battery-electric cars, etc,** get their drive energy from their batteries and must be recharged from an electric source

- **A hybrid electric vehicle (HEV)** cannot be charged from the mains (or charge station) but has a battery and electric drive. Main drive energy comes from liquid fuel

- **A plug-in hybrid electric vehicle (PHEV)** can be charged from an electrical source and be driven using either its battery or liquid fuel

- **Plug-in electric vehicle (PEV)** is a catch-all term for any of the above that can be completely or partially recharged from an electric source (mains or charge station).

Subsequently, car manufacturers such as Chevrolet, Nissan and Honda began unveiling electric cars. The Chevy Leaf was the first commercially available plug-in hybrid EV, which had a gasoline engine supplemented by an electric drive. Slowly, countries such as the US, China, Germany, Norway, and Netherlands began investing in setting up an EV ecosystem in their respective countries. Utility pilot programmes began for charging stations, federal incentives were declared to bring EVs into the mainstream.

California, a region which was one of the earliest adopters of EVs in the world, became a test case for infrastructure build-out charging programmes. Three Californian utilities – Southern California Edison, Pacific Gas and Electric Co and San Diego Gas & Electric began piloting public charging stations and variable pricing programmes to woo consumers and propel California to become a pioneer in EV adoption in the country. Meanwhile, sales in other countries such as China, Norway and Germany began rising. Norway's monthly EV sales surpassed monthly ICE sales in mid-2017 and continue to grow strong (77% of new vehicle sales comprised of EVs in March 2019)[1] on the back of significant monetary and non-monetary incentives as well as increasing choice of EV models. It is one of the most advanced markets for EVs in the world, constituting ~57% of new car sales in the country in 2018, up from ~3% in 2013[2]. France's EV market grew tepidly, reaching close to 150,000 EVs on-road (~3% of global EV stock), driven by industry push and insourcing of EV components. In the US, market share rose steadily to reach ~1.2% in end-2018.

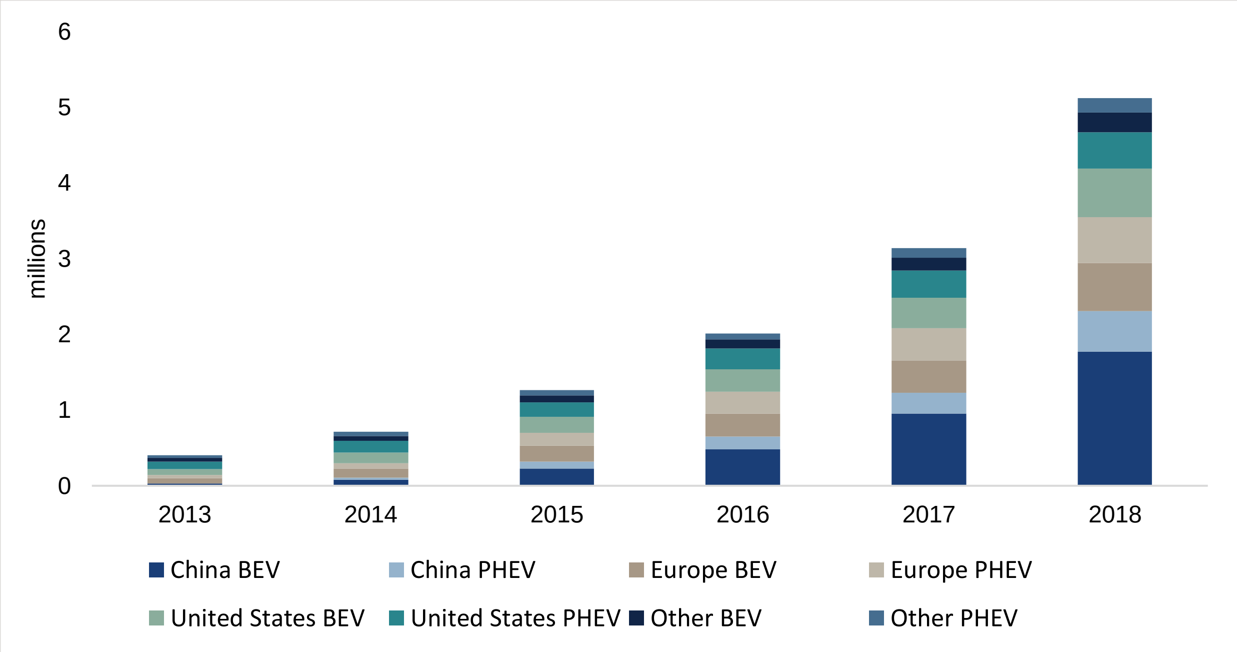
With fuel prices remaining low in the country, the operating cost advantage of EVs in the US was staggered. However, the biggest EV penetration (in terms of volume and sales) occurred in China. The nation outperformed all other countries on both the market side (EV sales, available models, investment in

[1] Norwegian Road Federation, https://fingfx.thomsonreuters.com/gfx/editorcharts/NORWAY-AUTOS-ELECTRIC/0H001PBM05K7/index.html

[2] Norweigian Road Foundation, https://www.rystadenergy.com/newsevents/news/press-releases/current-pace-of-ev-sales-in-norway-sets-the-stage-for-rapid-future-vehicle-fleet-electrification/

charging infrastructure) as well as the industry side (component manufacturing).

Figure 5: Global EV Fleet



Source: IEA

As of end-2018, the global stock of EVs surpassed 5 million, an increase of 63% (3.14 million in 2017) from the previous year (IEA estimates). China led the deployment, accounting for ~45% of the electric car fleet, followed by Europe (24%) and the US (22%).

2.3 Factors Driving the Change

Following are some of the factors driving the change towards:

1. Financial incentives: The rise in EV adoption is mainly governed by policy and regulations (federal and state). Financial incentives such as vehicle registration, exemption of applicable taxes and free access to toll roads are the most influential parameters. In Norway, EVs are exempt from acquisition tax, value-added tax and enjoy privileges such as free ferry rides and free parking in some cities. In the UK, government gives subsidies to buyers of EVs based on vehicle category. The amounts of grants for different EV classes are given below:

Table 5: The Amounts of Grants for Different EV Classes in the UK

Category Name	Basis of classification	Grant
Car	CO_2 emissions of less than 50g/km and can travel at least 112km (70 miles) without any emissions at all	35% of the purchase price for these vehicles, up to a maximum of £3,500
Motorcycles	The grant will pay for 20% of the purchase price for these vehicles, up to a maximum of £1,500	20% of the purchase price for these vehicles, up to a maximum of £1,500
Mopeds	No CO_2 emissions and can travel at least 30km (19 miles) between charges	20% of the purchase price for these vehicles, up to a maximum of £1,500

Category Name	Basis of classification	Grant
Vans	CO_2 emissions of less than 75g/km and can travel at least 16km (10 miles) without any emissions	20% of the purchase price for these vehicles, up to a maximum of £8,000
Taxis	purpose-built taxis and have CO_2 emissions of less than 50g/km and can travel at least 112km (70 miles) without any emissions at all	20% of the purchase price for these vehicles, up to a maximum of £7,500
Large vans and trucks	CO_2 emissions of at least 50% less than the equivalent conventional Euro VI vehicle that can carry the same capacity. They can travel at least 16km (10 miles) without any emissions at all	For the first 200 orders the grant will pay for 20% of the purchase price for these vehicles, up to a maximum of £20,000. The grant will then pay for 20% of the purchase price for these vehicles, up to a maximum of £8,000
Category 2 cars	CO_2 emissions of less than 50g/km and can travel at least 16km (10 miles) without any emissions at all	No plug-in grant
Category 3 cars	CO_2 emissions of 50 to 75g/km and can travel at least 32km (20 miles) without any emissions at all	No plug-in grant

Source: Government of the UK

France has put in place purchase subsidies of 6,300 euros for EVs and 4,000 euros for plug-in hybrids (only private car, van or specialized motor vehicle with CO_2 emissions between 0 to 20 g are eligible),[3] and a diesel scrappage plan with offers up to 2,500 euros for new plug-in hybrid and 3,700 euros for new EVs while trading with an old diesel vehicle, aged over 13 years[4]. Germany introduced a purchase incentive in 2016, earmarking 600 million pounds to rake up EV sales. In China, the national Electric Vehicle Subsidy Program grants subsidies for purchase of EVs, depending on vehicle range, battery pack size and energy efficiency.

2. Fuel economy: Several economies have mandated fuel economy and emission regulations governing the transport sector. With nations moving towards more stringent regulations (Euro 6 in the EU region, BS-VI in India), vehicle manufacturers are incentivised to invest in emission-free EVs. The European Union has stiff penalties under the 2021 emission reduction program to enable phase-out of conventional, fossil fuel-driven vehicles. China has brought in stiff standards for electric two-wheelers from April 2019, which will propel transition to Li-ion scooters from the more polluting lead-acid ones. The UK has hinted at introducing congestion charges in more cities (Leeds, Birmingham, Derby) after London and non-EVs are liable to pay higher charges than EVs. Several manufacturers across the globe have come up with elaborate plans to move away from internal combustion engines and embrace EVs.

[3] European Alternative Fuels Observatory, https://www.eafo.eu/countries/france/1733/incentives
[4] Economist Intelligence Unit, https://www.eiu.com/industry/article/1547321338/france-expands-diesel-car-scrappage-scheme/2018-11-07

Table 6: Transition to Electric Cars by Major Manufacturers

Manufacturer	Plans to Transition to Electric Fleet
General Motors	Plans to phase out petrol and diesel-powered engines, to have an "all-electric future". No timelines provided, however will introduce 20 EVs by 2023
Ford	Created "Team Edison" to focus on research and development of electric cars. Pledged to invest close to $4.5 billion over the next 5 years, starting from 2018 and aims to release 13 new all-electric models by 2023
VW Group	To invest $84 billion for EV development, with ~$60 billion for battery production. Plans to offer close to 300 EVs (all electric and hybrid versions) by 2030
Volvo	Plans to electrify entire vehicle line-up by 2019, with five all-electric models to be rolled out from 2019 to 2021
Renault, Nissan, Mitsubishi	The alliance intends to work jointly to develop new systems for use in upcoming EV lines. Plans to release 12 EVs by 2022
Daimler (parent company of Mercedes-Benz)	To invest $1 billion in Alabama plant for production of all-electric SUVs and a battery facility. A total of $10 billion shall be infused in EV development. Plans to electrify its complete portfolio by 2022, offering 50 electric and hybrid models
Toyota and Mazda	Jointly develop EV technology for use in future electric models. Pledged $1.6 billion to build a plant in the US, dedicated to development of electric and hybrid vehicles

Source: Company disclosures

3. Customer demand: EVs being offered today come with a gamut of features: performance, quiet ride, low running cost, unique exterior and interior styling. This technological progress has instilled trust among customers to make a jump from conventional vehicles to EVs. Rise in disposable income, improvement in ancillary services (charging infrastructure, flexible power rates) and the associated status quotient of owning an EV has pushed down the stratum of EVs from being "elusive" to "aspirational".

2.4 Barriers Against Adoption

Despite global acceptance and fast-paced improvement in the EV ecosystem, EVs are still to gain popularity for their utility.

Table 7: Major Challenges for EV Adoption

	Barriers	Prospective Solutions
Demand-side barriers	High cost	• Provide financial and non-financial incentives • Encourage discounts on utility rates • Enabling EV aggregators (taxi fleet, corporate fleet)
	Limited enabling infrastructure	• Improve charging infrastructure to reduce range anxiety • Incentivise instalment of chargers

	Barriers	Prospective Solutions
		• Encourage subsidised/ free parking for EVs • Create designated lanes along thoroughfares
	Consumer scepticism towards advantages of EV	• Apprise consumers of low running costs, total cost of ownership (after subsidising EV upfront costs) • Adopting fast charging, battery swapping to reduce idle time and waiting anxiety
Supply-side barriers	Lack of supply chain development	• Provide manufacturing incentives to enable domestic EV manufacturing: provision of industrial land, GST rebate, tax holidays, lower import duties • Step up R&D in battery manufacturing and other ancillary parts
	Grid optimisation	• Incorporate new monitoring levels, protection and control systems to improve capacity, reliability and efficiency • Utilise batteries in network to address capacity constraints and improve power availability

A lot of developments are expected to disrupt the EV space in the next 10 years. Several countries such as Germany, Italy and Australia have been building Home Energy Management Systems (HEMS) centred on domestic EV charging. HEMS economics are expected to reach grid parity soon, thereby unleashing a new packaged way of charging EVs. Detachable/swappable Li-ion batteries, which reduce the overall upfront costs, are being experimented with in emerging countries such as India. Battery management and manufacturing are seeing innovations making the batteries lighter and allowing rapid charging. These innovations are expected to propel EV sales globally in the years to come.

3 Evolution of Battery Technologies and Chemistries

Battery technologies play a pivotal role in delivering advancements in several industries, from power storage to EVs. The fast growth of the EV market is hinged on the development of new battery technologies that help make more efficient and advanced vehicle powertrains. There are three major groups of EVs in the market – hybrid EVs (HEVs), plug-in HEVs (PHEVs), full electric vehicles (EVs). HEVs are just like conventional ICE vehicles in which the propulsion systems are connected with electro motors, driven by batteries that charge through regenerative braking. A PHEV has a battery that can be charged through an external electricity source and also by its on-board engine and generator. Full EVs rely solely on electricity for charging. The batteries used in these three classes of vehicles vary owing to difference in degree of reliability on on-board battery systems.

Table 8: Battery Chemistries Required Across Different EV Segments

EV Class	Power Density	Charging time	Lifecycle
HEV	High	Extremely short	Long
PHEV	Medium	Short	Of less concern
Full EV	High	Short	Long

There are majorly three types of batteries used in EVs now.

1. Lead acid batteries
2. Nickel metal hydride (NiMH batteries)
3. Li-ion batteries

While lead acid and NiMH batteries are mature technologies, these types were originally used in early EVs. Lead acid batteries are heavy due to poor specific energy (34 Wh/kg) and are relatively inexpensive at present. NiMH batteries are considered superior, due to higher specific energy (68 Wh/kg), leading to lighter weight and lesser energy costs. However, due to low charging efficiencies and self-discharge properties (can discharge up to 12.5% per day under normal room temperature conditions), NiMH batteries have not been able to become mainstream.

Lithium ion (li-ion) batteries are now considered to be the standard for all modern EVs. Owing to advantages such as good specific gravity (140 Wh/kg), energy density and a low self-discharge rate (~5% per month), it has longer life and faster charging capabilities. There are several types of li-ion batteries, each having different characteristics and chemistries. Each combination has their own advantages and disadvantages in terms of cost, performance, safety and other parameters. The most prominent li-ion battery technologies used in automobiles are lithium-nickel-cobalt-aluminium (NCA), lithium-nickel-manganese-cobalt (NMC), lithium-manganese-spinel (LMO), lithium titanate (LTO) and lithium iron phosphate (LFP).

Table 9: Battery Technologies across Different Li-ion Battery Packs

Li-ion Battery Technologies	Specific Energy (Wh/kg)	Charge Rate	Cycle Life	Thermal Runaway
NCA	200-260	0.7C	500	150°C
NMC	150–220	0.7–1C	1000–2000	210°C
LMO	100–150	0.7–1C typical, 3C maximum	300–700	250°C
LTO	50–80	1C typical; 5C maximum	3,000–7,000	One of safest Li-ion batteries
LFP	90–120	1C typical	2000 and higher	270°C

Source: Energy Materials Industrial Research Initiative (EMIRI) Report

Although there is no single pertinent li-ion battery technology prevalent today, manufacturers design batteries keeping in mind five major trade-offs: *a)* Specific energy, which is the capacity of storing energy per kilogram of weight; *b)* specific power, which is the amount of power that batteries can deliver per kilogram of mass; *c)* performance, which means endurance of a battery during extreme climates and difficult terrains; *d)* life span; and *e)* cost.

Table 10: Trade-offs of Five Principal Li-ion Battery Technologies

	Specific Energy	Specific Power	Performance	Life Span	Cost per watt-hour
NCA	High	High	Moderate-High	High	Moderate
NMC	High	Moderate-High	Moderate-High	Moderate-High	Moderate-High
LMO	Moderate-High	Moderate-High	Moderate	Moderate	Moderate-High
LTO	Moderate	Moderate-High	High	High	Low
LFP	Moderate	Moderate-High	Moderate-High	High	Moderate-High

Li-ion is expected to be the battery technology that will prevail at least for the next one decade. However, it is very likely that new and better li-ion generations will emerge in the meantime.

4 Battery Swapping

In a battery swapping model, a depleted battery, residing in the vehicle, is replaced by a fully charged battery of the same architecture. Although the technical parameters for the battery swapping system would depend on the charging point of batteries and the swapping infrastructure. All batteries swapped in/out from the vehicle have to be homogenous. This is critical to maintain optimum battery life. Therefore, all battery swapping stations must stock the same battery (common battery technology and chemistry) to cater to the common swapping ecosystem in the country. The more disparate are the onboard batteries on different EVs, the more cumbersome and cost-inefficient will be the stocking process. All vehicle manufacturers across a segment (2-W/3-W) who intend to be part of the battery swapping ecosystem need to form a cohort and finalise battery technology which can then be rolled out across models and manufacturers. However, it is unlikely to happen. Internationally, the battery swapping model has not succeeded due to differences around standardisation, commercial reliability and viability. Several manufacturers wanted to have an exclusivity in battery dynamics (which is the heart of an EV) and some even set up their own charging infrastructure (for instance, Tesla).

The advantages and challenges of a battery swapping system (BSS) is given below:

Table 11: Advantages for a BSS

Low cost of ownership for EVs	The battery costs, which account for ~40% of the EVs' total upfront cost is high and hinders sales due to high TCO. With swappable battery system, the ownership of the battery shifts from the vehicle owner (end user) to the manufacturer or swapping service providers
Reduction in charging time and extension in travel range	A typical battery swapping takes around 10-15 minutes as against a 5-12 hours for charging over a charging station based on vehicle category and charging speed. This improves reliability and confidence in an EV. The EV owner can make longer trip distances by accessing fast battery swapping services. Also, charging of batteries over a station is subject to faster depth of discharge and depletion, which can be avoided via battery swapping
Postponement of charging of batteries at BSS to night time or off-peak hours	With the responsibility of charging of batteries shifting from EV owners to BSS operators, a controlled charging strategy can be scheduled. The BSS, which is a large variable load, can be charged during off-peak hours, thereby reducing the risk of potential peak demand and system overloading

The table below specifies some of the challenges that are typically faced for the deployment of a battery swapping system (BSS).

Table 12: Challenges for Deployment of BSS

Standardisation of EV li-ion battery packs	It has not yet happened globally. Majority of the auto OEMs prefer to keep tight control over their design strategies of battery packs as it is at the core of an EV
Reliability of leased/ rented battery packs	In case of a BSS, the auto manufacturer sells/ leases/ rents batteries to the BSS operator. However, the authenticity of the BSS operator, in terms of customer service, is questionable. Any short change, on behalf of the operator, will lead to loss of credibility and trust
Commercially viable business models	Governments in SAARC Member States (SMS) have not given any clarity on policy with respect to battery swapping in the country. There is no precedence of commercially sound business models for battery swapping as well. This leaves significant risk and uncertainty

5 Global EV Charging Standards

An EV can be charged through AC (alternate current) or DC (direct current) charging devices. The battery of an EV requires DC, therefore a DC charger can be directly plugged into the vehicle to initiate charging. Alternatively, the vehicle can be connected to an AC charger where the input AC supply is converted to DC using an on-board AC-DC converter. The time required to charge an EV through AC charging depends on the single-phase AC output (220 V standard for India and 120 V for the US), current rating of the charger and output rating of the AC-DC converter. For example, a 220 V AC, 15 Amperes supply will lead to AC output of 3.3 kW, which subsequently connected to an EV with a 10 kW on-board battery pack through an AC-DC converter of output 1 kW DC will take 10 hours to fully charge the battery. On the other hand, DC fast chargers (DCFC) have higher power output and charge an EV battery much faster due to loss aversion in the AC-DC converter side.

Typically, there are different types of AC and DC chargers with different communication protocols. It is important that the battery pack in the vehicle communicate with the charger (irrespective of type and protocol) through a “handshake” mechanism. The different chargers and protocols being followed for EV charging are as follows:

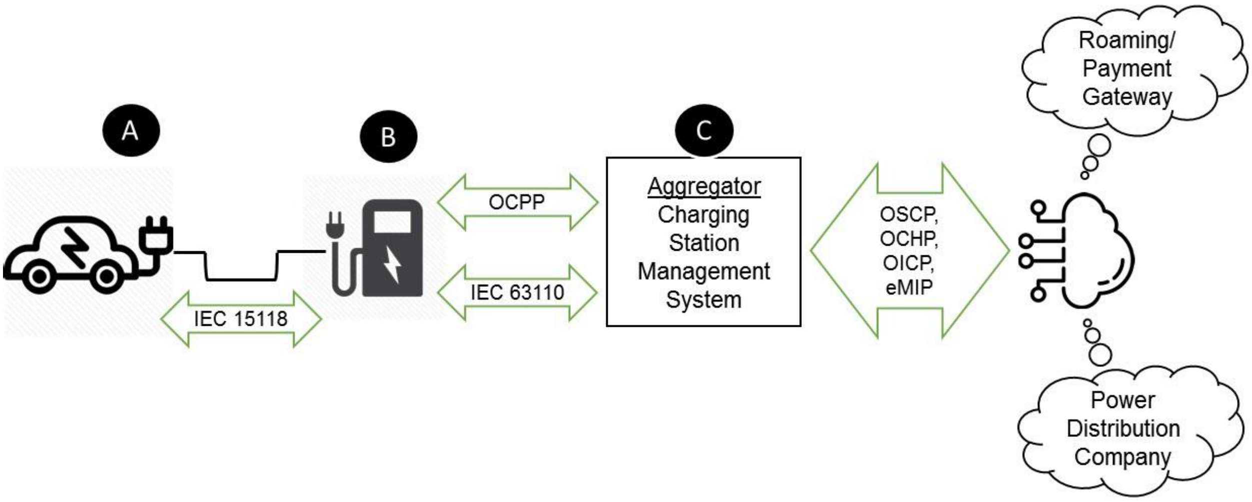
Table 13: Chargers and Protocols for EV Charging

Charger Type	Geographical Usage	Maximum Power Output and Communication Protocols
A. AC Chargers		
Type 1 with Yazaki Socket	Japan, USA	Up to 7.4 kW
Type 2 with Mennekes Socket	Europe (majorly Germany)	Up to 44 kW
Type 3 with Le Grand Socket	France, Italy	Up to 22 kW
B. DC Chargers		
CHAdeMO	Originated in Japan, most popular DC charger globally, used in US and Europe	Up to 400 kW DC charging; Control Area Network (CAN) for communication
GB/T	China, Bharat Chargers in India	Up to 237.5 kW DC charging; CAN for communication
Tesla Super Charger	The US and Europe wherever Tesla cars are sold in large numbers	Up to 135 kW DC charging; CAN for communication
C. Combined (AC and DC) Chargers		
Combined charging system (CCS)	CCS-1 and CCS-2 versions are available - the same plug is used for both AC and DC charging; used majorly in Europe	Up to 43 kW AC and up to 400 kW DC (1000 Volt x 400 Amp); Power Line Communication (PLC) for communication

Japan and Korea have adopted CHAdeMO, Europe has adopted CCS, while US has all four types of DC chargers. Many EV manufacturers sell adapters to connect to other chargers (Nissan Leaf is sold with CCS adapters in Europe and Tesla sells CHAdeMo adapters) to improve interoperability.

The charging standards for EVSE not only take into consideration charging stations and communication protocol between EV and stations, but also include an entire gamut of ancillary services. The complete scope of standards is shown below:

Figure 6: Various Charging Standards for EVSE



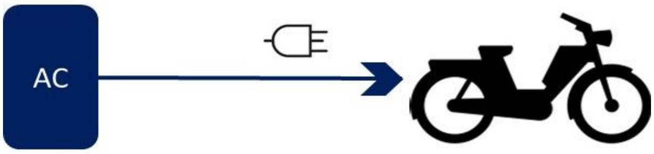
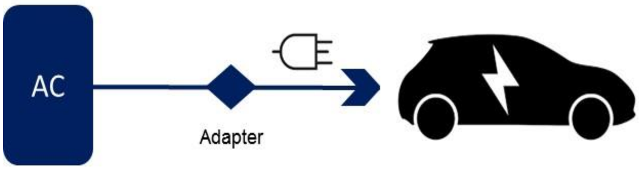
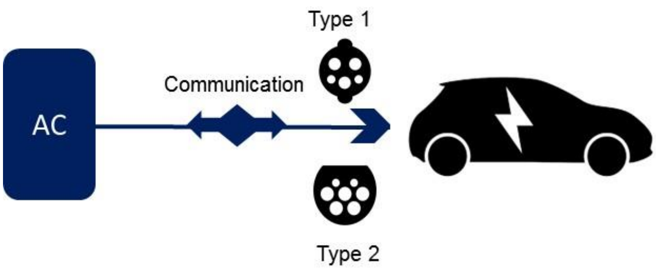
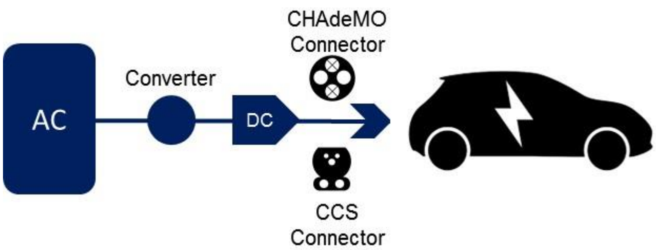
Note: IEC: International Electrotechnical Committee, OCPP: Oper Charge Point Protocol, OSCP: Open Smart Charging Protocol, OCHP: Opern Clearing House Protocol, OICP: Open Inter Change Protocol, eMIP: eMobility Inter-Operation Protocol

The standards discussed earlier pertain to standards and communication protocol between points A and B, i.e. the EV and the charging station which sits outside the system and provides DC/ AC as per configuration. Part 24 of IS 17017 or IEC 15118 pertains to digital communication systems over ethernet protocol.

The OCPP or IEC 63110 pertains to the communation protocol between B and C, i.e. the charging station and the charging management system (CMS). Considering the charging station (B) to be an internet of things (IoT) device, there is an embedded controller inside the charging station which communicates with a CMS system, which in turn communicates with several other IoT-enabled charging stations. The entire mesh of stations communicates through OCPP/ IEC 63100 with the CMS, drawing power from the grid or transacting with the grid utility. While OCPP is an open source protocol, IEC 63100 takes into consideration several security measures such as cyber security to ensure over-the-air secure contracting. The communication between B to C gives the utility direct control over all charging stations remotely. Communication protocols such as OSCP, OCHP, nOICP and eMIP enable communication between a CMS and other market makers. Protocols can be used for data gathering (charging profiles of EVs, time of use, and peer to peer communication between market players such as clearing house and grid operators). This will help the utility manage the load by monitoring important parameters such as degree of power drawl, degree of stress in the local sub station, etc. Through digital communication channels with the stations, grid support functions (load management/ tariff-based controls for peak shaving) can be implemented. Further, by enabling energy flow from EV to the grid during peak period, demand-side response as well as smart charging can be enabled, building an ecosystem for vehicle to grid (V2G).

Globally, there are no universal charging standards for EVs. Europe defines four charging modes; each mode varying in power rating, type of connection (AC/DC) and charging speeds. They are illustrated below:

Table 14: Modes of EV Charging in Europe

Mode 1: Household socket and extension cord  	• Vehicle is connected through standard three-pin socket in residences • Charger in vehicle converts AC to DC and controls battery charging • Allows for a maximum power delivery of 11A **<u>Usability</u>: Small motorcycles, electric bicycles**
Mode 2 : Non-dedicated socket with cable-incorporated protection device  	• Connected to power grid through household socket outlets • Deploys an adapter in charging cable to improve reliability • Charging is done in a single-phase or three-phase network and installation of an earthing cable **<u>Usability</u>: Transitional solution before mode 3 was mainstreamed**
Mode 3 : Fixed, dedicated circuit socket  	• Connected to electrical network thorugh specific socket, plug and dedicated circuit • Maximum power output is 7.4 kW in a single phase and 22 kW in three phases **<u>Usability</u>: Recommended day-to-day AC charging method**
Mode 4: DC connection  	• Charging done in DC through an off-board charger, allowing the system to withstand high power • Maximum power output is 50 kW for CHAdeMO, 120 kW for Tesla and 350 kW for CCS **<u>Usability</u>: Commercial fast charging stations**

Additionally, advanced EV charging methods like pulse charging, inductive charging (uses an electromagnetic field to transfer electricity to a PEV without a cord) are being used.

The US, on the other hand, classifies standards of EVSEs based on charging power output, commonly known as "levels".

Table 15: Levels of EV Charging in the US

	Level 1	Level 2	Level 3
Outlet	Standard	High voltage circuit	Very high voltage circuit and three-phase power
Type of charging	AC	AC	DC
Maximum power range (kW)	1.4	19.2	90
Voltage rating (V)	120	240	480V and above

While levels 1 and 2 are for charging through a single-phase voltage in residential and commercial buildings, level 3 charging is through three-phase voltage, via AC or DC.

China has adopted its own charging standards - GB/T - which is capable of fast charging at a maximum of 237.5 kW. The country is working on a new GB/T standard which will be made available in 2019/2020. Furthermore, China is working with the CHAdeMO network to jointly develop an ultra fast charging standard.

The type of charging requirements for a vehicle is mainly driven by the vehicle architecture, i.e. the battery size and chemistry, and these are explained in the table below:

Table 16: Typical Battery Sizes and Number of Charges Requirement According to Vehicle Type

Vehicle Type	Battery Size	Vehicle Efficiency	Avg. km Run	km per Charge	No of Charges Required
	kWh/vehicle	km/kWh	km/day	km/charge	charges/year
e-2W	1.5	50	20	60	120
e-3W	4.5	20	100	70	515
e-4W (personal)	15	8	40	100	144
e-4W (fleet)	15	8	200	100	720
e-Bus (intra city)	120	1	200	100	720

An e-2W will require charging every three days, whereas a commercial e-4W and an e-bus will require charging thrice every day.

Battery chemistry is a crucial factor in determining the correct method of charging. Bigger the battery size, higher is the requirement of charger rating. There are different cells with varied chemistries. The major three, though, are NMC, LFP and LTO.

LTO is a premium battery with long lifecycle, fast charging and high thermal stability. However, it is bulky and expensive. NMC, on the other hand, is compact (in size and weight) and costs less. The downside is that if an NMC battery is charged fast without taking into consideration battery management, it impacts the battery lifecycle. LFP, which resides between LTO and NMC, is being phased out.

Another important factor for selecting the right battery is the **power train voltage of the vehicle**. Each vehicle has a specified power train voltage, based on which battery voltage and charging current limit is determined. This, in turn, helps in deducing the charging power limit for the vehicle, without compromising on battery degradation.

Table 17: Typical Battery Voltage and Current Limits Across Classes of EVs

Vehicle Type	Electric Power Train Voltage	Battery Voltage	Charging Current Limit	Charging Power Limit
2W	48V	48V	10A	500 W
3W	48V	48V	15A	750 W
4W	72V	72V	75A	7 kW
Bus	650V	650V	45A	30 kW

On board AC-to-DC charger rating that comes with EVs often limits higher power level for off-board AC charging. For example, the on-board charger for e-Verito limits the charging limit to 2.3 kW.

The communication protocols between EV and EVSE is the next important factor in determining the correct charging method for an EV. When a low voltage vehicle (2W or 3W) with a low powertrain voltage is connected to a charging station, the vehicle can be charged safely as the current limits are low. However, in the case of a 4W or an e-bus, where powertrain voltages are high, it is very important to secure the connection between the charger and the vehicle such that the on-board electronics are safe. As highlighted before, each charging method (CHAdeMO, CCS, or GB/T) has different current and voltage limits, connector requirements and communication protocols. However, interoperability of charging modes remain a concern.

6 Impact on Grid for High Scale EV Adoption

Several studies and research papers have highlighted the potential impact of EV charging stations on the distribution network. For different EV penetration scenarios, quantifiable impacts were measured on several distribution networks across voltage loadings. In order to understand the detrimental effects of large-scale EV charging on the grid, it is important to understand how an electric grid works.

Individual generators, through a variety of sources (coal, natural gas, nuclear, hydro, solar, wind, etc.), produce electricity to meet end-use power demand (as captured by system load). System load is transient and is susceptible to changes, based on power usage. Some generators (majorly coal and nuclear power plants) produce power at a steady basis to contribute to baseload demand of the system. Others (majorly gas-based plants) are manipulated accordingly (ramped up or down) by adjusting to spikes and troughs in the load. More variable technologies such as solar and wind are used whenever these are available. At any point of time, there is a 'reserve margin', i.e. a specified amount of backup power-generating capacity to account for potential forecasting errors and unscheduled power plant shutdowns.

Transmission lines carry high voltage electricity over long distances from the generators to the distribution network. Once power reaches close to the end-users, the high voltage is stepped down and delivered to the consumer via the distribution network. Several systems have been put in place to maintain reliable power distribution, such as load forecasting measures (to schedule power supplies sources accordingly), usage of spinning generators (to arrest change in frequency), and usage of advanced power electronics (to control reactive power through the transmission and distribution system).

Traditionally, large conventional generators provide for power demand (baseload as well as peak). However, off-late, distributed generation, energy storage, and demand response measures are being incorporated to make the grid more reliant and improve variability-handling capacities.

Table 18: Measures of Reliability for an Electric Grid

Customer-oriented reliability indices	SAIFI	Number of times a customer experiences interruption during a particular time period
	SAIDI	Average duration of interruption per customer
	CAIDI	Average duration of interruption for customers interrupted during a particular time period
Energy-oriented reliability indices	ENS	Total energy not supplied (energy deficiency) by the system
	AENS	Energy not served during a particular time period (average system load curtailment index)

The typical charging load profile for a 15-kWh Li-ion car battery using AC-001 and DC-001 chargers are shown below. The AC charger uses a 3.3 kW charger and requires ~five hours to charge, whereas a DC charger uses a 15-kW charger and requires less than two hours.

The AC mode is a constant current charging where power continuously keeps rising, after which the power settles during a settling time period. The impact of the charging method will be a 3.3 kW charging load on the peak load for a duration of five hours. In case of the DC mode, the battery is charged to ~80% in one hour, and the peak contributed by the charging is ~15 kW.

Therefore, depending on individual chargers, load profiles, and voltage and current profiles, peak contribution will vary. When aggregated across different vehicles and different chargers deployed at different time periods over a day, the load contribution from EV chargers in a region can be deduced at a regional grid level.

The major consequences of uncoordinated charging of EVs are:

- Distortion of voltage profile
- Change in system harmonics
- Increase/ change in peak load behaviour

Forum of Regulators (India) had assessed the impact on a transformer due to charging of EVs (slow as well as fast charging). Several scenario-based analyses were carried out through system simulation over a period of 24 hours.

In order to simulate a system of varying sizes, two sets of inductance and resistance parameters were selected. Set one consisted of a small network of renewable energy generators located within 5 km from a diesel generator located within 1 km from the point of demand. Set two had generators located at different points, with a wind generator located farthest at 25 km from the load.

The major scenarios and output results have been tabulated below:

Table 19: Scenarios Pertaining to Residential Load

	Case 1 (slow charging)	Case 2 (Fast DC Charging)	Case 3 (Fast DC Charging)	Case 4 (Fast DC Charging)
Impedance	Impedance values from Set 2	-	Impedance values from set 1	Impedance values from set 2
Baseline	Residential load (10 kW)	Residential load (10 kW)	Residential load (10 kW)	Residential load (10 kW)
Scenario 1	Baseline load + 0.66 MW EV load (24 kWh battery capacity, 100 EVs)	Baseline load + 4 MW EV load (85 kWh battery capacity)	Baseline load + 4 MW EV load (85 kWh battery capacity)	Varying EV and residential loads
Scenario 2	Baseline load + 0.66 MW EV load (85 kWh battery capacity, 100 EVs)	Baseline load + 8 MW EV load (85 kWh battery capacity)	Baseline load + 8 MW EV load (85 kWh battery capacity)	
Scenario 3	Baseline load + 1.32 MW EV load (24 kWh battery capacity, 200 EVs)	Baseline load + 8 MW EV load (24 kWh battery capacity)	Baseline load + 8 MW EV load (24 kWh battery capacity)	
Scenario 4	Baseline load + 1.32 MW EV load (85 kWh battery capacity, 200 EVs)	Baseline load + 4 MW EV load (24 kWh battery capacity)	Baseline load + 4 MW EV load (24 kWh battery capacity)	
Scenario 5 (Peak coincident charging)	-	-	Baseline load + 4 MW EV load (85 kWh battery capacity)	-

Source: Forum of Regulators (India)

For a commercial feeder, the impact of EVs on the distribution network was assessed on a transformer with 95% loading. The commercial load was also simulated for two power ratings of 6.6 kW and 40 kW with two battery capacities of 24 kWh and 85 kWh.

Table 20: Scenarios Pertaining to Commercial Load

	Case 1 (No Impedance)	Case 2 (Set 1 Impedance)
Baseline	Commercial load (10 MW)	Commercial load (10 MW)
Scenario 6	Baseline + EV load (4 MW 85 kWh)	Baseline + EV load (4 MW 85 kWh)
Scenario 7		Baseline + EV load (0.66 MW 24 kWh)
Scenario 8		Baseline + EV load (0.66 MW 85 kWh)

Source: Forum of Regulators (India)

Table 21: Outcome Pertaining to Residential Load

		Case 1	Case 2	Case 3
Scenario 1	Voltage drop (%)	0.013%	1.70%	1.60%
	Rise in maximum demand (%)	-0.08%	16%	13%
Scenario 2	Voltage drop (%)	0.002%	2.20%	2.00%
	Rise in maximum demand (%)	0.15%	39%	36%
Scenario 3	Voltage drop (%)	-0.006%	2.20%	1.80%
	Rise in maximum demand (%)	0.72%	36%	35%
Scenario 4	Voltage drop (%)	0.002%	1.70%	1.50%
	Rise in maximum demand (%)	1.64%	12%	11%
Scenario 5	Voltage drop (%)			11.7%
	Rise in maximum demand (%)			38.6%

Note: Scenario where distortion in voltage was greater than 6% has been highlighted in red
Source: Forum of Regulators (India)

For cases 1, 2 and 3, the residential load was kept constant at 10 kW. For Case 4, EV load was varied from 4 MW to 20 MW, and residential load was varied from 4 MW to 20 MW.

The results are as follows:

Table 22: Voltage Drop and Increase in Peak Demand with Change in EV Load

Residential Load (MW)		**Voltage Drop**			**Increase in Max. Demand**		
		4	8	12	4	8	12
Electric vehicle load (MW)	4	1.036%	0.465%	2.374%	36%	16%	13%
	8	1.196%	1.913%	5.043%	85%	36%	27%
	12	2.323%	3.672%	8.69%	139%	57%	41%
	16	3.130%	5.304%	12.67%	153%	65%	52%

Note: Scenarios where distortions in voltage were greater than 6% have been highlighted in red
Source: Forum of Regulators (India)

With the model being simulated on a commercial load of 10 MW, an EV load of 4 MW (40 kW rated capacity charger) was used for Scenario 6 and 0.66 MW (6.6 kW rated capacity charger) was used for simulation.

Table 23: Outcome Pertaining to Commercial Load

Scenarios	Parameters	Case 1	Case 2
Scenario 6	Voltage drop (%)	0.64%	0.66%
	Rise in max. demand (%)	36%	23%
Scenario 7	Voltage drop (%)	-	0.56%
	Rise in max. demand (%)	-	1.31%
Scenario 8	Voltage drop (%)	-	0.56%
	Rise in max. demand (%)	-	1.31%

Note: Scenario where distortions in voltage were greater than 6% has been highlighted in red
Source: Forum of Regulators (India)

6.1 Outcome of the Study

Allowable variations on supply of low voltage is +6% to -6%. In residential feeders, on several occasions, the voltage drops surpassed 6%. It was observed that for transformers with less than 50% baseline load, rise in ~20% of EV load will not lead to voltage deviations beyond allowable limits. For transformer loadings beyond 90%, occurrences of transient fluctuations rise significantly. Slow charging does not have any adverse impact on any of the feeders. However, DC fast charging causes significant rise in peak loads and drop in voltage levels.

7 Considerations for Selecting EV Charging Locations

The key factor for setting up a charging station is usability of the station. There have been several research studies conducted to assess the key elements for determining charging station locations in a geographical area. The major determinants for planning a charging network vary on type of geographical area under consideration.

Station planning for a metropolitan area would follow a node-based approach, whereas areas on major inter-city thoroughfares could use a flow-based approach.

Metropolitan regions serve as congregation of EVs, where charging demands are at the origin or the destination for intra-city travel. Therefore, node-based planning uses the origination-destination (OD) approach, where charging stations are strategically placed to optimise usage emanating from intra-city travel (which constitutes majority of travel behaviour in a city). Flow-based approach, on the other hand, is suited for station planning at a state level. This entails mapping of major inter-city highways and expressways passing through the region and subsequently assessing the traffic demand across the routes. Upcoming industrial and commercial clusters, and development of smart cities along a road corridor are major considerations while forecasting incremental traffic. The approach is equivalent to planning of pumping stations along a highway.

The major differences between the two approaches are:

Table 24: Modalities of Node and Flow-based Approaches

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

7.1 Number and Types of Stations Needed

Demand-side planning to assess the number of PCS within a geographical area will take into consideration:

- **Static EV population in an area**: Assessment of end-use demand of charging is paramount in planning the trunk infrastructure. This needs to take into consideration average miles driven by an

EV, average time to recharge, and travel behaviour of EV owners (used for short intra-city trips/ long duration trips)

- **Floating EV population in an area**: A commercial hotspot of a city attracts vehicles far more than the static EV population of the region. This necessitates additional charging requirement
- **Charging behaviour of EV buyers**: While majority of the charging (~95%) in the US is done at home and office, the presence of PCS provides psychological comfort to EV owners. Hence, the degree of charging via PCS needs to be objectively deduced before planning for the same. The number of PCS per EV also starkly varies between geographies, ranging from five in Europe to ~40 in China. This shows variation in usage of PCS among countries

Once the average charging demand and, therefore, the aggregate PCS is determined, site and location planning are key determinants to assess a station's business viability.

8 Country in Focus: Bhutan

8.1 Present EV Sales and Charging Infrastructure

The government of Bhutan introduced electric vehicles (EVs) in the country in 2013 in keeping with its policy to remain carbon neutral and reduce import of fossil fuel. Since then, the government has offered fiscal incentives, devised policy regulations, and set up quick charging (QC) stations with free charging where the users need not pay to charge their EVs. However, the uptake of the EVs has been rather slow. According to the record maintained by the Road Safety and Transport Authority (RSTA) of Bhutan, there are only 102 EVs in the country as of June 2019.

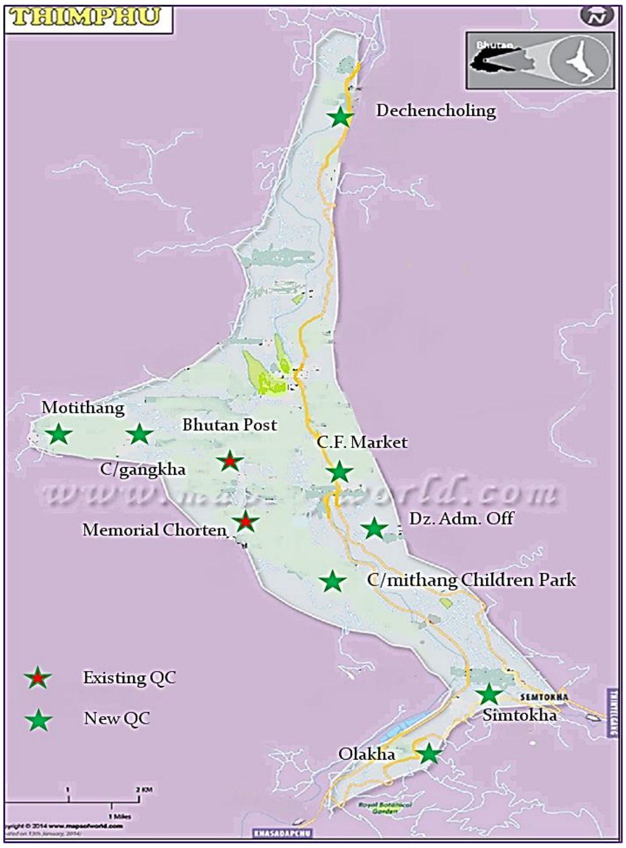
Table 25: Growth in EVs in Bhutan

Year	Total Vehicles
2013	7
2014	7
2015	7
2016	97
2017	93
2018	93
2019	102

Source: RSTA, 2019

All the EVs in Bhutan are in capital Thimphu and Paro. For 102 EVs, there are four quick charging stations, two each in both the cities. It is assumed that all the EV owners have home chargers (HCs) which enable charging of the vehicle at home. In Thimphu, the QCs are located at Bhutan Post and memorial Chorten. The existing QC is CHAdEMO for the Nissan Leaf model. There are three models of EVs available in the country – the Nissan Leaf, Mahindra Rewa and Mitsubishi Outlander (PHEV). The Rewa and Outlander do not have specific QC model of their own and uses CHAdEMO. The government plans to install eight more QCs in core Thimphu in 2019. Bhutan is expected to have 10 QCs in Thimphu and two in Paro by the end of 2019.

Figure 7: Installation Points of Existing and Proposed QCs in Thimphu



8.2 Regulations and Federal Policies Driving EV Adoption

The Royal Government of Bhutan, in an endeavour to push EV sales, has not imposed any taxes on EVs. The existing taxes on different classes of vehicles are as follows:

Table 26: Taxes Levied on Vehicle Categories in Bhutan

Vehicle Category	Taxes Levied
Light vehicles below 1,500 cc	100% tax (45% customs duty, 45% sales tax, and 10% green tax)
1,500cc – 1,799cc	115%
1,799 – 2,500 cc	120%
2,500cc – 3,000 cc	125%
Above 3,000 cc	180%
EV	0%
Hybrid vehicles up to 1,500 cc	45% (20% customs duty, 20% sales tax, and 5% green tax)
Hybrid vehicles greater than 1,500 cc	50%

Source: Income tax Act of Bhutan

Moreover, the Bhutan Sustainable Low-emission Urban Transport System project offers subsidy of $5,500 for EVs. The total tax on hybrid vehicles increases by 5% for higher engine capacity.

The following are some of the government policies:

- Bhutan's Vision 2020, a 20-year strategy for national development, places transport and infrastructure development at the core of its strategy and, inter alia, highlights the need for the development of a safe, reliable and comfortable system of public transport. A national strategy and action plan for low carbon development has been prepared, which seeks to reduce GHG emission significantly – by 15% by 2040, which is on top of the expected decrease of 8% in the business-as-usual scenario
- Bhutan National Transport Policy 2017 seeks to provide "the entire population with a safe, reliable, affordable, convenient, cost-effective and environment-friendly transport system in support of strategies for socio-economic development"[5]. The policy supports the principles of inclusiveness, sustainability, sound asset management, effective governance and an emphasis on low carbon transport solutions such as EVs
- The Nationally Determined Contribution (NDC) submitted in 2015 affirmed the government's target of remaining carbon neutral pledged in 2009 at the 15th session of the United Nations Framework Convention on Climate Change (UNFCCC). The NDC notes that the emissions from the transport sector are showing a rapidly increasing trend and identifies the promotion of low carbon transport system as a key mitigation measure. Bhutan's First National Communication (2000) and Second National Communication (2011) to the UNFCCC both report significant contributions of the energy sector to the national GHG emissions. Options for the transport sector included promotion of alternative fuels, electric and hybrid technologies and mass transport systems
- The 11th Five-Year Plan (2013-2018) includes 'carbon neutral/green and climate resilient development' as one of its 16 key results and the plan envisages the introduction of eco-friendly, safe, reliable, affordable and alternative modes of transport. The draft 12th Five-Year Plan (2019-2024) also identifies promotion of EVs as one of the key programmes of the transport sector to address environmental issues and reduce dependency on fossil fuels, and contribute to national key results, such as remaining carbon neutral and enhancing climate and disaster resilient development
- In order to establish clean, safe and affordable and reliable mass transportation systems, the Economic Development Policy (EDP) 2017 explicitly recommends the introduction of an

[5] MoIC, "National Transport Policy 2017", Second draft, Ministry of Information and Communication, Royal Government of Bhutan, 2017.

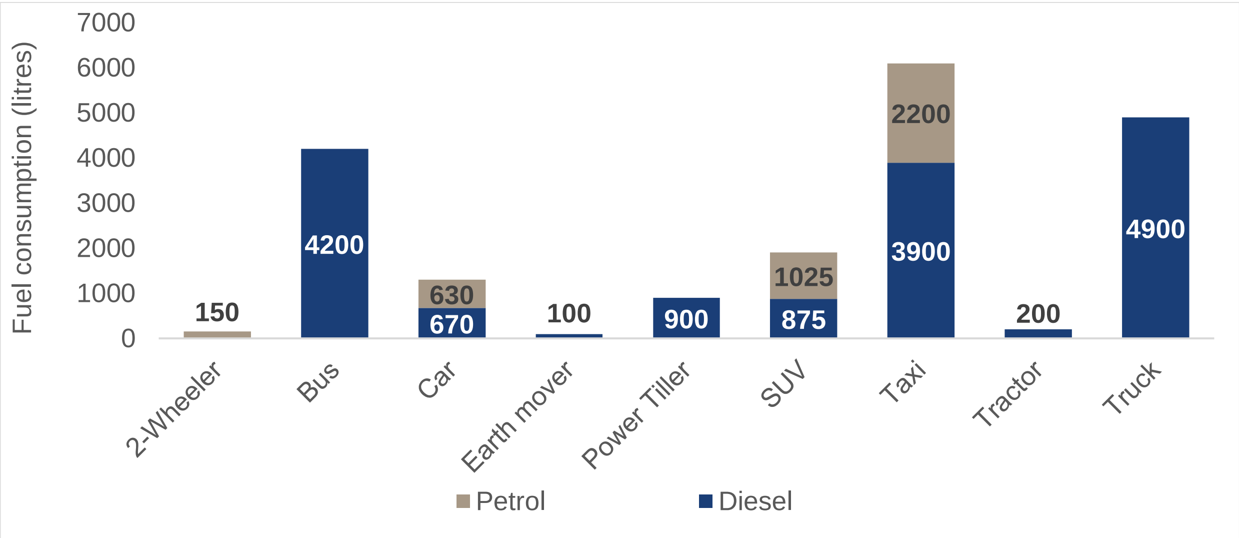
electric/hybrid public transport system in major urban centres. It also encourages to provide subsidy and incentives as targeted intervention wherever economic viability is at stake due to low mass

- The draft Vehicles Emission Road Map proposes a comprehensive package of policy measures to control vehicle emissions which Bhutan intends to implement until 2025 to maintain clean air and reduce CO_2 emissions by the transport sector by an additional 25%. It also proposes clear incentive instruments and targets for the purpose

8.3 Outlook on EV Sales

In order to give an impetus to the country's carbon neutral policy, promote sustainable transport system, and improve energy security, the Royal Government of Bhutan (RGoB) plans to support rollout 300 more EVs by February 2021 under the Bhutan Sustainable Low-emission Urban Transport System project funded by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP-GEF 2018). These new EVs will replace at least 300 existing taxi fleet in Thimphu, Paro, Haa, Wangdue, Punakha, and Phuentsholing. By 2021, it is estimated that Bhutan would have 402 EVs (102 existing plus 300 new). The EV programme in the country is being managed by the Ministry of Information and Communication (MoIC). The government has publicised the project in the media, inviting interested taxi drivers to register for the EV programme. Under the project, the government will provide 20% subsidy (max of $5,500) and financial institutions will provide loan equity of 50%[6]. As the taxis are estimated to consume more than 6,000 litres of fossil fuel per year, it is envisioned that the replacement of the taxi fleet will help reduce fossil fuel import and greenhouse gas (GHG) emission substantially.

Figure 8: Fuel Consumed in a Year by Different Vehicles in Bhutan in 2015 (in Litre)



Source: DRE, 2015

[6] Kuensel, http://www.ekuensel.com/index.php/user/pdfView/1600, viewed on 31 September 2019.

Two scenarios were considered while estimating the number of EVs likely to be added over 2022-30 – low uptake and high uptake. In the low uptake scenario, it was assumed the EVs will clock 10% compounded annual growth rate (CAGR) and in high uptake 20% CAGR. The forecast is based on the following assumptions and limitations:

- CAGR of 10% was based on the historical growth rate of vehicles over 2013-2018
- The forecast includes both replacement and new vehicle registrations
- The government continues to support with financial subsidy/tax rebate and policy regulations to make EVs affordable to general public
- Vehicle fuel price is steadily increasing and there is no subsidy on fossil fuel
- There are adequate and easily accessible public electric vehicle charging stations (EVCS) and the EV users do not face operational challenges
- The country's GDP is steadily rising and people can afford and are willing to switch over from conventional vehicles to EVs
- There are enough and willing takers for EVs

Table 27: Forecast of EVs in Bhutan

Year	Low Uptake	High Uptake
2022	442	482
2023	486	579
2024	535	695
2025	589	834
2026	647	1000
2027	712	1200
2028	783	1440
2029	862	1729
2030	948	2074

8.4 Assessment of Power Distribution Utilities

8.4.1 Country Macros and Policy Frameworks Guiding Utilities' Overall Performance

Bhutan is a small country in South Asia, sandwiched between China and India in the Himalayas. Because of its geographical location, it is endowed with huge hydropower potential. Only about 2.335 GW of the total 24 GW potential is utilised till date. The generating stations are managed by Druk Green Power Corporation (DGPC). The Bhutan Power Corporation Ltd (BPC) is the operator of the transmission and distribution network. The transmission network is interconnected with the Indian grid for exporting power to Indian states.

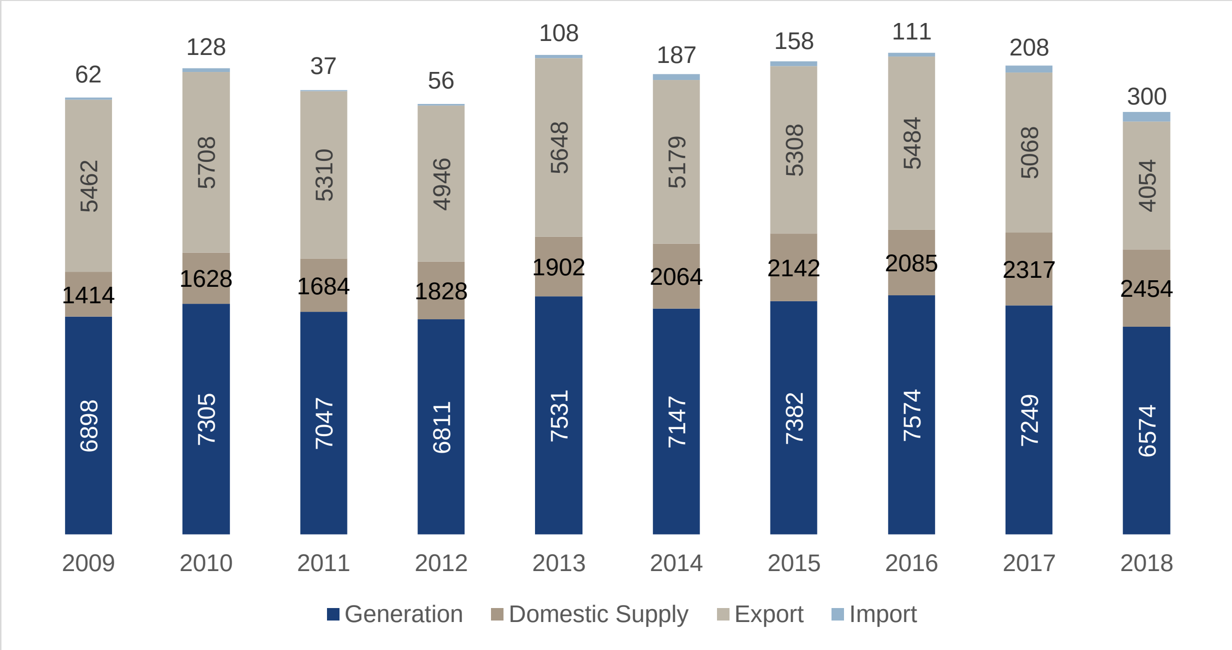
Currently, power is transmitted across the country mostly through 132 kV and 66 kV transmission lines. More high voltage transmission lines are expected to come up by 2020. These lines have the potential to reduce the losses incurred. Around 59% of the lines in the country are 132 kV and 30% 220 kV. The 400 kV lines were established in 2015 and they transmit power from Tala hydropower station to Malbase and Pagli which is interconnected with Indian grid for exporting power to India. The transmission and distribution network is not only indicative of the access to electricity but also serves to demonstrate the probable loss in the system. Longer lines with lower voltage can lead to greater losses in the system. There are very few high voltage lines except Tala-Malbase and Tala-Pugli. Setting up high voltage lines across the country is a challenge due to the difficult terrain. Reaching some of the less populated pockets is highly cost-intensive. Economically, it is more feasible for those regions to generate power through pico, micro, mini and small hydel projects or through other stand-alone renewable resources such as solar and wind.

BPC was formed as an offshoot of the erstwhile Department of Power, the then Ministry of Trade and Industry and was launched as a public utility on July 1, 2002. The corporatisation of the utility was expected to result in greater efficiency and better delivery of services in the power sector. Later the ownership of BPC was transferred to Druk Holding and Investment Ltd (DHI), the commercial arm of the government established through the Royal Charter in 2007 "to hold and manage the existing and future investments of the Royal Government for the long-term benefit of the people of Bhutan".

DGPC is a company that operates and maintains hydropower assets of Bhutan. It was established in January 2008 by merging the three hydropower corporations of Basochhu, Chhukha, and Kurichhu under DHI. Tala was merged with DGPC in 2009. Since then, DGPC has grown significantly. Bhutan's current hydropower installed capacity is 1,615 MW. With about 70% of the generated energy exported to India, hydropower revenue forms 27% of the country's exchequer and offsets much of the balance of payments with India. The sector accounts for about 13% of the country's gross domestic product. The total electric power generation amounted to 6,573.990 million units (MU) in 2018. The net energy exported to India, including the royalty[7] energy, was 4,053.588 MU. The quantum of electricity supplied to BPC for domestic use was 2,454.306 MU. The national coincidental peak load during the year was 399.35 MW.

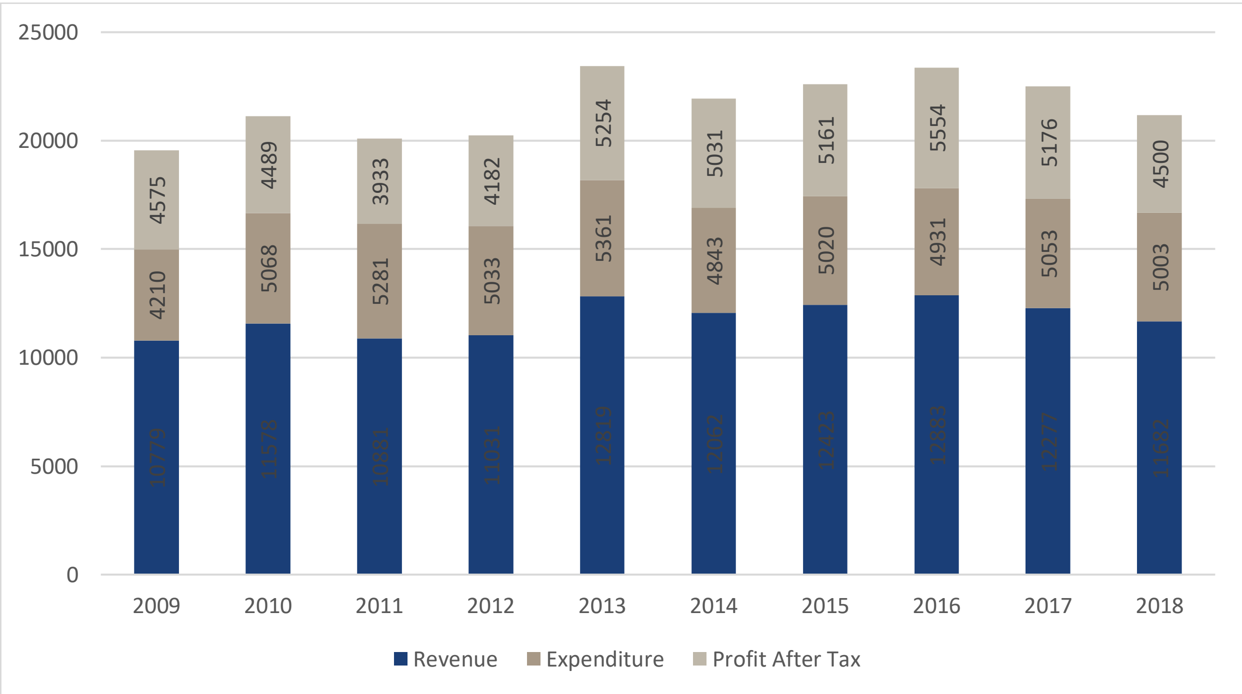
[7] Basochhu, Chhukha, Kurichhu, and Tala hydropower plants which are fully owned by the RGoB have to provide 15% of the annual generation as royalty energy to RGoB free of charge.

Figure 9: Generation, Import, Domestic Supply and Export of Electricity in Bhutan (MUs)



Source: DGPC, 2018

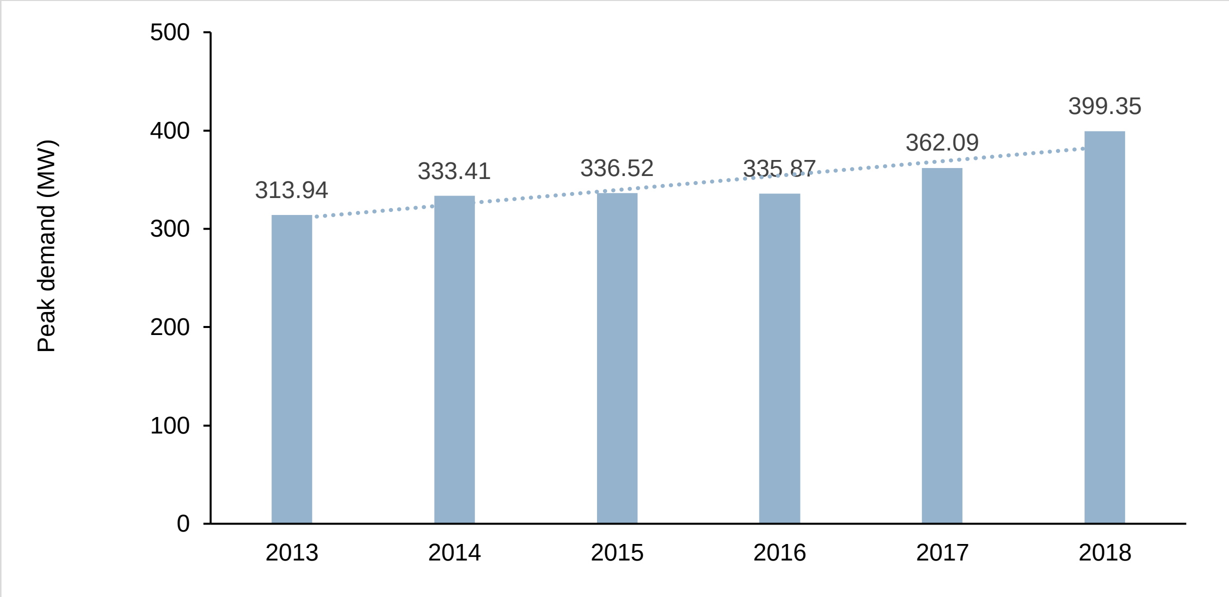
Figure 10: Revenue, Expenditure, and Profit for the Sale of Electricity in Bhutan (Million Ngultrum)



Source: DGPC, 2018

The figure below shows the system peak during the last six years. As is evident from the data, the demand has been increasing steadily. Therefore, for the successful implementation of the EV project, the power distribution system will have to be boosted so that it can take up the additional load when a large number of EV charging stations are integrated with it.

Figure 11: System Peak Demand in Bhutan



Source: NSB, 2018 and BPC, 2018

The domestic demand for electricity has been steady and the peak demand recorded was 399.35 MW on December 27, 2018, at 1818 hours. The second highest was 362.09 MW recorded November 14, 2017 at 1900 hours. BPC's customers are categorised as high voltage (HV), medium voltage (MV), low voltage bulk (LV bulk) and low voltage (LV) customers. The 16 HV customers remained same in 2017 and 2018. Meanwhile, its MV customers increased from 59 in 2017 to 63 in 2018 and LV bulk reduced from 778 to 775. The company has seen steady increase in LV customers over the years even after completion of major Renewable Energy (RE) programs. The LV customers increased from 184,277 in 2017 to 191,998 in 2018, an addition of 7,722 customers. BPC today serves more than 192,852 customers in the country. The increase was mostly a result of electrification of rural homes through continuing RE programs.

In order to meet the domestic demand for electricity, 2.5 GWh of energy was purchased from DGPC in the year 2018 compared with 2,326.384 MU in the previous year. The internal generation from embedded mini and micro hydel plants owned by the company, including generation from diesel generation sets was 19.24 MU during the year 2018. BPC also imported 0.064 MU from Assam State Electricity Board (ASEB) and 0.258 MU from West Bengal State Electricity Board (WBSEB).

The total sale during the year 2018 was 2,328.44 MU, up 6.5% from 2,185.75 MU in the previous year. The energy wheeled for export to India for DGPC decreased to 4,437.920 MU from 5,306.564 MU in the previous year largely due to lower power generation by DGPC and some increase in domestic consumption.

BPC has been maintaining its transmission and distribution (T&D) losses in limits comparable within the region. Of the total energy of 6,919.03 MU received by the system during the year 2018, 6,766.36 MU was utilised. This translates the global energy loss for the year 2018 to 2.21% compared with 2.00% in the previous year. The domestic T&D loss (excluding wheeling) in 2018 was 6.15% compared with 6.54% in 2017. The company has been able to maintain its losses within permissible limits due to timely preventive and planned maintenance and up gradation of its network system.

The total value of the company's assets increased to Nu. 30,056.79 million from Nu. 28,964.16 million in 2017. There is a decrease in the net worth of the company from Nu. 22,984.53 in the previous year to Nu. 21,965.80 million in 2018 due to adjustments in investment reserved on transfer of Dungsam Cement Corporation Ltd. shares to DHI. The gross assets added during the year are Nu. 3,583.70 million compared with Nu.1,262.49 million in 2017.

In order to improve power reliability and, most importantly, to meet the increasing demand, distribution planning and system expansion are carried out across the country whenever required. The expansion of the primary distribution system is usually carried out as turnkey projects. Some of the noticeable works carried in the current year are the supply and construction of 33/11kv, 2 x 5MVA GIS substation at Tshongdue, Paro and the upgradation of 33/11 kV, 1x2.5 MV AIS substation to 2x2.5 MVA GIS substation, Phobjikha, Wangduephodrang. Some of the new projects in progress are the supply and construction of 33/11kV, 2x2.5MVA substation at Denchi, Pemagatshel, and conversion of 33kV AIS to GIS Panels at 33/11kV Changangkha Substation, Thimphu.

8.4.2 Shortlisted Utility

In Bhutan, the sole distribution utility, BPC was selected for detailed study and development of roadmap of EV charging infrastructure in the country.

8.5 Planning for the Transition

8.5.1 Charging Standards

Broadly, there are two types of EV chargers – the conventional charger or the home chargers, usually attached to the residential buildings, and QCs, located at the charging station. The type and standard of EV chargers vary with the region where it is used. There are three recommended QCs for EVs – combined charging system (CCS), CHAdeMO, surface vehicle recommended (SAE) combined charging system. For the convenience of EV owners, slow charger such as the home charger and on-board chargers are equipped with the vehicles so that the user can charge at home or at the workplace. The quick charger takes about 20-30 minutes while the home charger takes three-four hours.

Based on the specification of the EVs currently plying in Bhutan and proposed EV taxi project funded by the UNDP-GEF, it is recommended to have either CCS Combo-2 QC or CHAdeMO fast DC chargers. During the course of this study, we talked to a few taxi drivers and also drivers who used EVs in the past. One of the issues raised by the users is EV users sometimes had to wait as there were others already charging at a station. The users recommend for two chargers per QC station as shown below.

Figure 12: Existing and Recommended QC Station in Bhutan

Existing QC *Recommended Combo-2 QC*

The RGoB has selected four EV models for support from the UNDP-GEF project[8]. They are Nissan LEAF e-NV200 (Hatch Back from Nissan Motors), Ioniq (Hatch Back from Hyundai Motors), BYD–T3 (Mini Van from BYD Group), and iEV7S AUDA EU5 AUDA (SEDAN from Auda Motors). The recommended QC is CCS and CHAdeMO as these chargers support all the four identified models of EVs[9]. Based on the existing QC users, it takes approximately 30 minutes to achieve 80% SoC.

8.5.2 Number of Chargers

The number of QCs required during 2022-30 was estimated based on the following factors:

- Same EV model selected for implementation through the UNDP-GEF project will be continued beyond 2021
- Every EV is supplied with slow AC/home chargers and EV drivers/owners prefer slow chargers to QCs as it adversely affects the life of the battery
- The minimum range of fully charged EV is approximately 200 km for new EVs. Therefore, once the EV is fully charged overnight at home, it doesn’t require frequent charging at QCs
- Gradient and condition of the road network due to which the mileage per full charge may decrease
- Driving habits of Bhutanese drivers may further decrease the mileage per full charge
- Charging stations are distributed along the highway and core public place

[8] MoIC, “Notification”, Ministry of Information and Communications, Royal Government of Bhutan, August 2019.

[9] Gopal, K., “Proposed Technical Specifications for Electric Vehicles and Charging Infrastructure for Bhutan Sustainable Low-emission Urban Transport Systems Project”, UNDP-GEF, Bhutan, April 2019.

As of June 2019, there are 102 EVs in the country and the government plans to support rollout of another 300 EVs by February 2021 through the GEF project. In addition to existing four QCs, 23 more is proposed to be set up. Thus, there will be 27 QCs for 402 EVs, i.e. one QC for 15 EVs. As the EV models selected for the UNDP-GEF project has 200 km mileage per full charge, a ratio of one QC for every 20 EVs is recommended. Further, it is assumed that one HC would be installed for every EV at the owner's home. The table below shows number of QC stations by 2030.

Table 28: Number of Projected QC Stations in Bhutan

Year	Low Uptake	High Uptake
2022	22	24
2023	24	29
2024	27	35
2025	29	42
2026	32	50
2027	36	60
2028	39	72
2029	43	86
2030	47	104

8.5.3 Grid Augmentation

The average power consumed by CHAdeMO QC is 50 kW and by HC is 7.4 kW. However, in effect, the amount of power drawn from QC will depend on State of Charge (SoC) and battery efficiency. Assuming all QCs are operated at the same time, the additional power capacity required by 2030 will be 2.36 MW for low uptake and 5.2 MW for high uptake. These numbers do not take into account the additional capacity required because of HCs. The impact on the distribution system will be substantial if the use of HCs coincides with the QCs. However, this is unlikely as HCs are mostly used overnight, whereas QCs are expected to be used during the day.

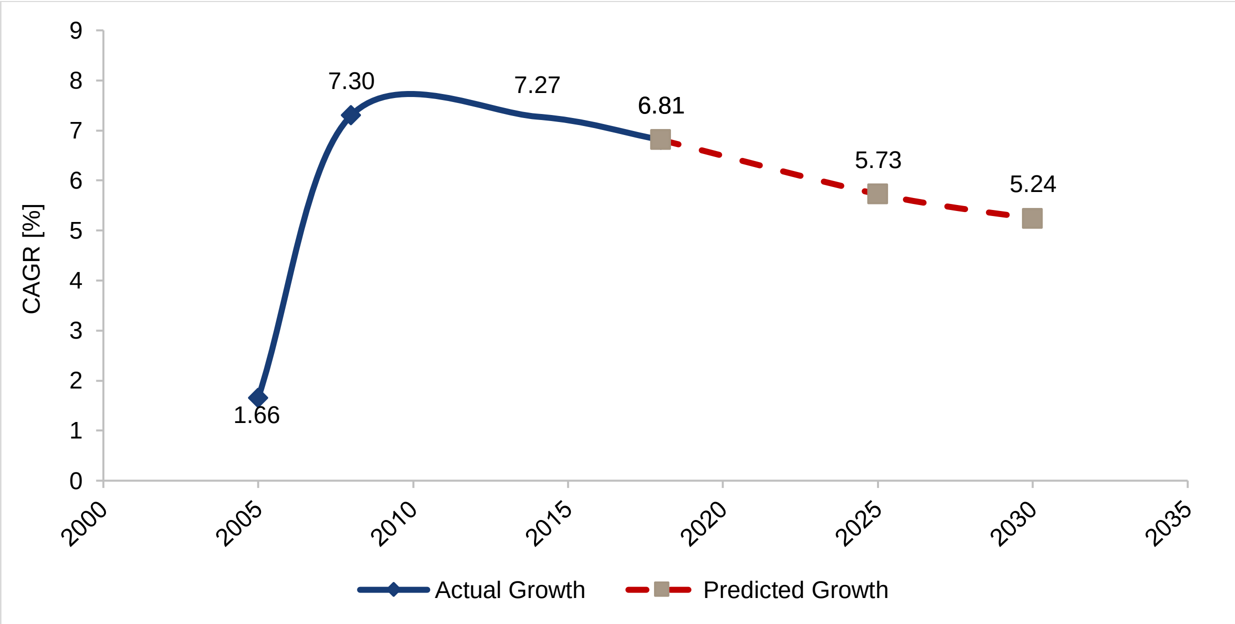
Impact on the Grid

Majority of the EVs are expected to be concentrated within Thimphu City and Paro. With the number of EVs increasing beyond 2021, the number of QCs is expected to increase substantially. The domestic load (power demand) of Thimphu could also increase in the next decade. The additional load due to EV together with domestic load will strain the transmission and distribution networks. Therefore, EV growth along with increase in domestic load will be essential to see whether Thimphu distribution network can handle the increased load.

Domestic load forecast for the next 10 years was projected by extrapolating data from 2010 to 2018. During the period, the load data rose at 6.81% compound annual growth rate (CAGR).

From 2019 to 2025, it has been assumed that the pace of domestic load is expected to decelerate to 5.73% CAGR. Up to 2030, this is expected to slow down further to 5.24% CAGR, as illustrated in figure below. It is assumed that after 10-15 years, there will be no significant load increase within Thimphu City as over 80% of the land area has already been occupied. Hence, growth could be from additional gadgets only that will be used by the residents.

Figure 13: Outlook of Domestic Load of Thimphu



As a consequence of the increase in domestic load along with EV load, the existing Thimphu distribution network (TDN) could get overloaded. In order to assess the capability of the existing TDN, a typical TDN was studied through modelling, using the DIgSILENT software. The model considered additional load from EVCS and increase in domestic load.

TDN has over 365 km of 33kV as well as 11kV (MV) lines, and ~400 km of LV lines, with more than 450 distribution transformers. The distribution lines to far-flung villages at the periphery of Thimphu Dzongkhag are on 33 kV systems, whereas local supplies are through 11 kV systems.

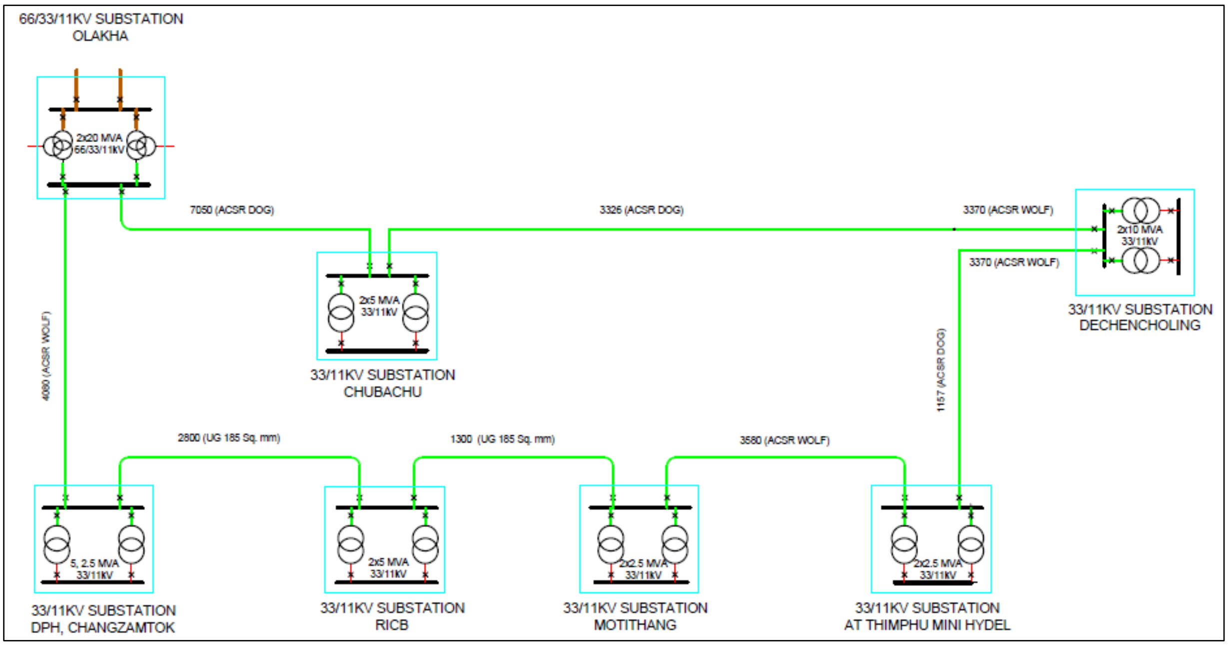
Figure 14: Overview of 33 kV Thimphu Distribution Network

Steady-state stability study is normally conducted to ensure that the systems are running at optimal efficiency and satisfying the demand of customers, without overloading the lines and equipment. Stability studies were conducted to confirm the health of the power elements, such as the voltage profiles, and the status of loading of each transmission and distribution lines, and transformers in various operating conditions.

Power flow studies are useful in selecting the right equipment, such as transformers and switchgear, and selecting the capacity of conductors and cables. These studies are essential before any major investment decisions are taken to assess economic viability. Voltage instability is caused by increase in load demand of end-users (demand for reactive power) or change in the system conditions that lead to uncontrollable voltage drop.

TDN was modelled in DIgSILENT Power Factory software. Figure 10 shows a single line diagram of 33/11 kV ring network, which represents the main supply source for 11 kV outgoing feeders. Existing loads as well as QCs up to 2030 were considered in the model. The assessment was conducted for worst-case scenario, where all QCs are assumed to be operated simultaneously. Under status quo, i.e., up to 2021 (with 402 EVs), there is no impact on TDN, and there is no need for a contingency plan.

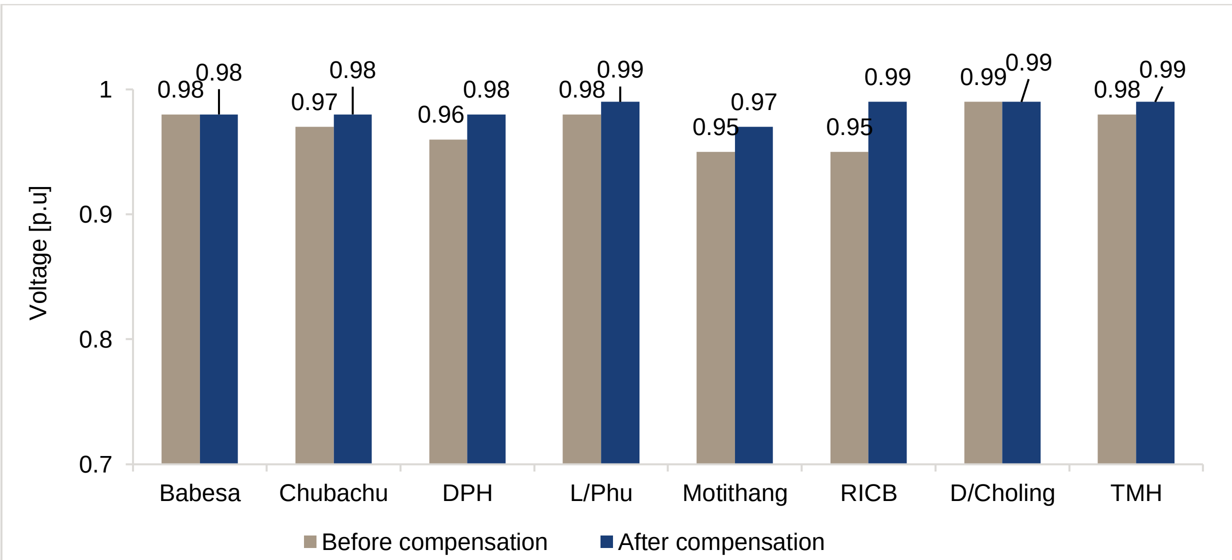
Figure 15: Single Line Diagram of 33 kV Ring Network of Thimphu



Low-Scale Adoption

Under this scenario, the voltage at Motithang and Royal Insurance Corporation of Bhutan (RICB) substations will drop below the permitted level of 0.95 per unit (p.u), as illustrated in Figure 11. This can be corrected by connecting one 0.96 mega volt amps (reactive) (MVAr) capacitor bank for Motithang substation and a 3.84 MVAr for the RICB substation.

Figure 16: Voltage Profile Before & After Compensation with Shunt Capacitors (Low Uptake Level)



The revised voltage at each substation after connecting the capacitor banks is shown in table below. By connecting one 0.96 MVAr capacitor bank at Motithang substation, its voltage could be improved from 0.95 p.u. to 0.97 p.u. Similarly, by connecting one 3.84 MVAr capacitor bank at the RICB substation, its voltage could be improved from 0.95 p.u. to 0.99 p.u.

Table 29: Voltage Compensation Requirement for Each Substation for Low Uptake Level (2030)

Substation	Shunt Compensator		Voltage [p.u]		Remarks
	No	[Mvar]	Before	After	
Babesa	0	0	0.98	0.98	Not required
Chubachu	0	0	0.97	0.98	Not required
Diesel Power House	0	0	0.96	0.98	Not required
Lungtenphu	0	0	0.98	0.99	Not required
Motithang	1	0.96	0.95	0.97	End customer voltage improved from 0.95 p.u to 0.97 p.u
RICB	4	3.84	0.95	0.99	End customer voltage improved from 0.95 p.u to 0.99 p.u
Dechencholing	0	0	0.99	0.99	Not required
Thimphu Mini Hydel	0	0	0.98	0.99	Not required

High-Scale Adoption

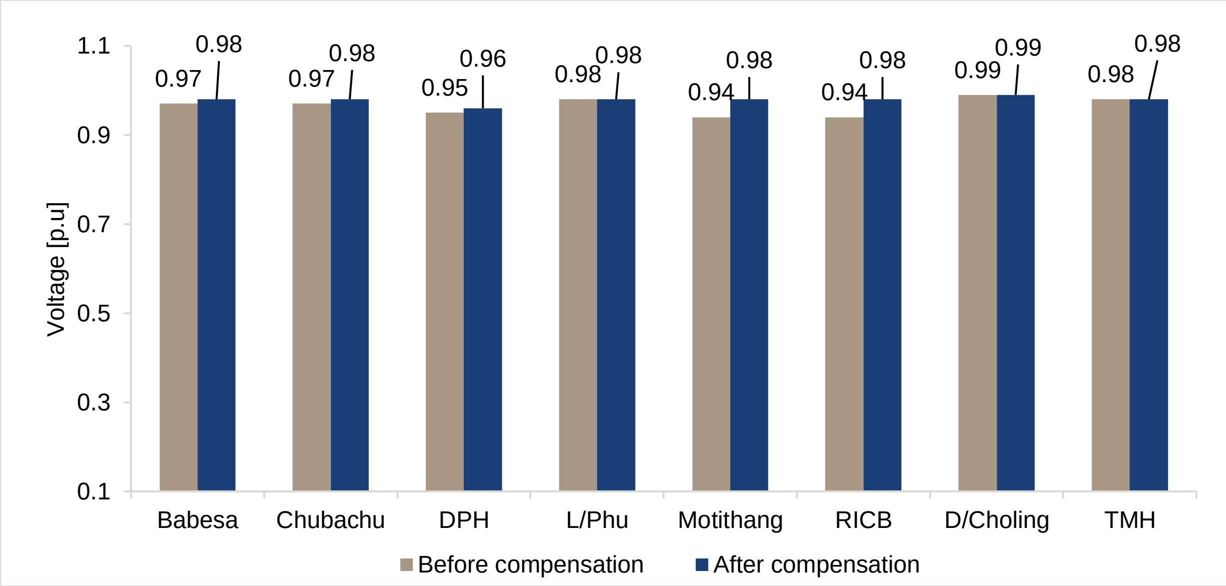
The voltage profiles for each substation before and after the compensation is shown in Table 5. Low voltage below 0.95 p.u. indicates a requirement for voltage compensation on that particular feeder. The capacitor bank required is 0.96 MVAr for Diesel Power House (DPH), 1.92 MVAr for Motithang, and 4.8 MVAr for RICB.

Table 30: Voltage Compensation Requirement for Substation for High Uptake Level (2030)

Substation	Shunt Compensator		Voltage [per unit]		Remarks
	No	[Mvar]	Before	After	
Babesa	0	0	0.97	0.98	Not required
Chubachu	0	0	0.97	0.98	Not required
Diesel Power House	1	0.96	0.95	0.96	All customers voltages are brought back to 0.96 p.u
Lungtenphu	0	0	0.98	0.98	Not required
Motithang	2	1.92	0.94	0.98	All customer voltages brought back from 0.94 p.u to 0.98 p.u
RICB	5	4.8	0.94	0.98	Majority of customer voltages improved from 0.94 p.u to 0.96 p.u but still for some customers tap changing of transformer is required

After adding the capacitor bank, the model was re-simulated and the values obtained are presented in Figure 12. The voltage level at all three affected substations could be restored to the permissible limit by adding capacitor banks.

Figure 17: Voltage Profile Before & After Compensation with Shunt Capacitors (High Uptake Level)



Power Demand of EV and its Impact at the Household Level

HCs rated at 7.2 kW used by existing household connections would have a substantial impact on the household's power consumption. The aggregated power demand of HCs alone will rise to 6.81 MW and 14.93 MW for low and high uptake, respectively. However, as the HCs will be used at night, it will not have any impact on the utility's distribution network.

Impact on Power Generation and Import

Additional loads due to EVs can have an impact on power generation and electricity imports during the lean winter months, when generation is low because of reduced flow of rivers. Bhutan imported ~110.64 MU and 207.89 MU of energy from India in 2016 and 2017, respectively, to meet its domestic load consumption (DGPC, 2017). By 2025, power demand will increase with the growth of EVs, with estimated demand for low and high uptakes at ~2.36 MW and 5.2 MW, respectively. The extra power generation requirement could lead to extra cost. However, the increased cost of power import could be substituted by the reduction in diesel import. On an average, a conventional taxi is estimated to consume 6000 litres of petrol/year[10]. To cover same distance with EV, the charging cost is Nu 112,500 @Nu 10/kWh which gives

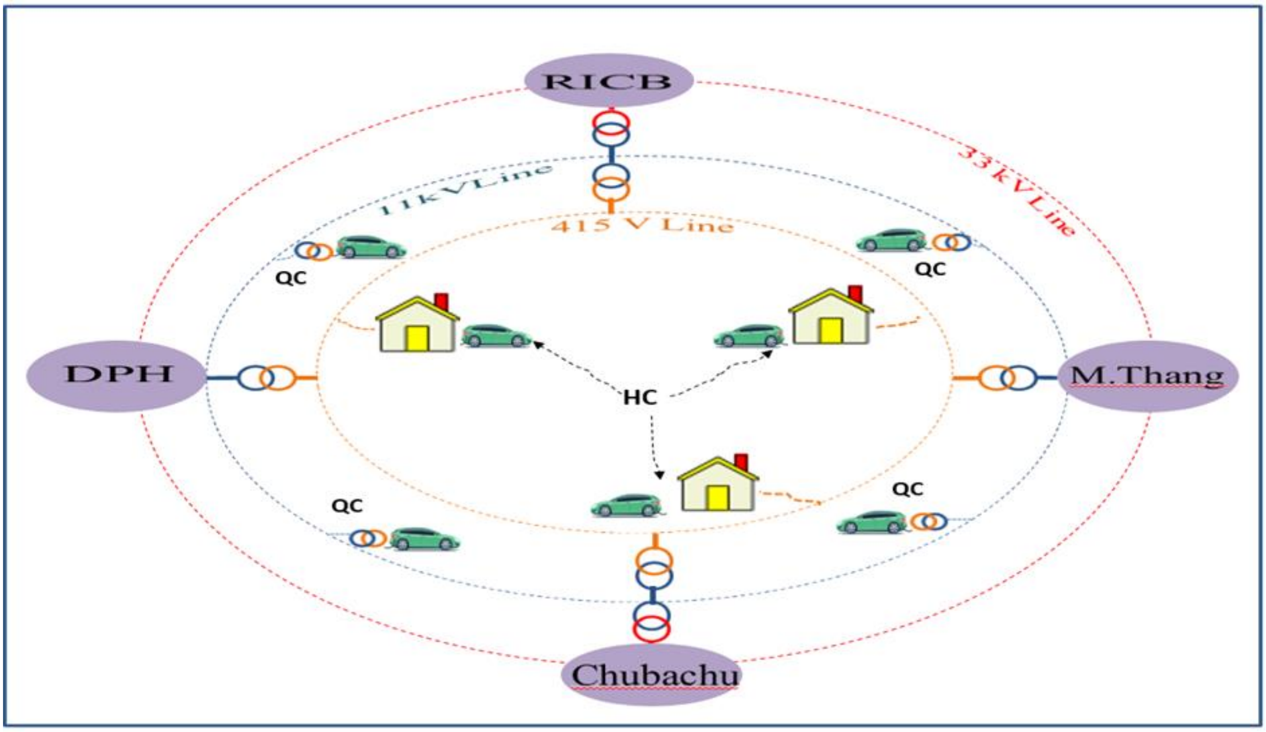
[10] DRE, "Energy Efficiency in Transport Sector", Department of Renewable Energy, Ministry of Economic Affairs, Royal Government of Bhutan, December 2015.

a total savings of Nu 271,500/car/year. Thus, for 300 new EVs, it has potential to save Nu 81.45 million/year which is equivalent to 1.8 million litres of petrol/year.

8.5.4 Charging Locations

QCs are connected on the local distribution grid through 11 kV sub-transmission lines. The figure below provides the architecture of how the QC is connected at the various locations on the distribution network.

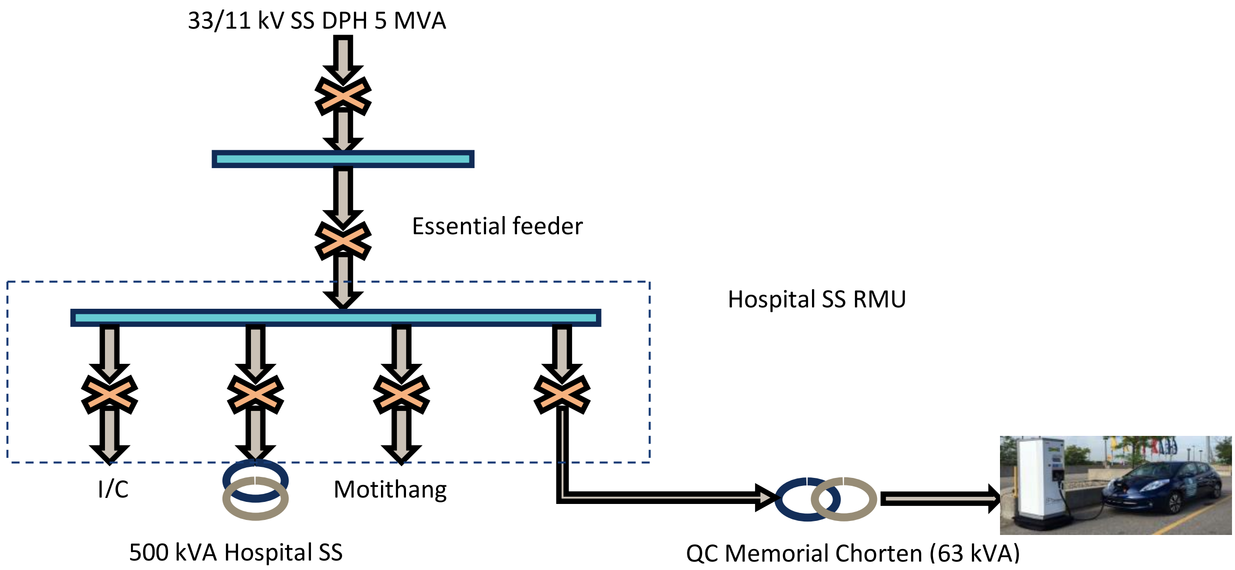
Figure 18: Architecture of EV QC and HC on the Distribution Network



QC is typically connected through a dedicated transformer 11/0.415kV of 63 kVA, with three-phase system. The supply line is further connected using underground (UG) cable (four core, 150 mm^2) to the low voltage distribution pillar (DP) of four ways, 400A with an inbuilt switch fuse unit for protection. A smart meter is also installed in the DP near the transformer to record the energy consumption of the EV.

The figure below shows the existing topology of the supply system to the existing QC station at Memorial Chorten. It is expected that connection of the upcoming QCs will have similar topology.

Figure 19: Power Supply Topology for QC Station at Memorial Chorten



Strategic location of EVCS could not only enable use of EVs without any operational challenges but also improve the viability of EVCS business. Apart from the initial cost of EV and its operational range, the accessibility to EVCS and cost of charging will have a direct impact on the adoption of EV. Therefore, the location of EVCS is critical to improve the adoption of EV as well to enhance business viability of EVCS. The RGoB has decided the location of 23 EVCS to be installed through UNDP-GEF funding (in *Table*)[11]. The locations include both the core city areas as well as highways.

Table 31: Tentative Location of EVCS by 2021

Region	Location	No. of EVCS
Paro	Core area	1
	Taktsang Base	1
Punakha	Khuruthang	1
Thimphu-Wangdue highway	Menchuna	1
Wangdue	Core area	1
Thimphu	Core area	8
	Dechencholing	1
	Tango base	1
	Khasadrupchu	1
Thimphu-Phuentsholing highway	Wangkha	2
	Gedu	1

[11] Project Management Unit of EV, "Personal Communication", MoIC, August 2019.

Region	Location	No. of EVCS
Phuentsholing	Core area	2
Paro-Haa highway	Bitekha	1
Haa	Core area	1

Tentative location of EVCS beyond the year 2022 is presented in below tables for low and high uptake respectively. The locations were chosen based on the visibility, likely utilisation rate, distance between the charging stations, and importance of the location area as this would have direct impact on the number of people driving to the area and use EVCS.

Table 32: Tentative Location of EVCS for Low Uptake by 2030 in Bhutan

Region	Location	No of EVCS		Total No of EVCS by 2030
		As of 2022	Additional between 2022-30	
Paro	Core area	1	2	3
	Taktsang Base	1	1	2
Punakha	Dzong parking	-	1	1
	Khuruthang	1	1	2
Thimphu-Wangdue highway	Dochula	-	1	1
	Hongtsho	-	1	1
	Menchuna	1	1	2
Wangdue	Bajo	-	1	1
	Metsina	1	1	2
Thimphu	Core area	8	2	10
	Dechencholing	1	1	2
	Tango base	1	1	2
	Buddha point	-	1	1
	Motithang Takin Reserve	-	1	1
	Khasadrupchu	1	1	2
Thimphu - Phuentsholing highway	Wangkha	2	1	3
	Taktikothi	-	1	1
	Gedu	1	1	2
Phuentsholing	Core area	2	1	3
Paro-Haa highway	Bitekha	1	1	2
Haa	Core area	1	1	2
Thimphu-Paro highway	Chhudzom	-	1	1
Total		**23**	**24**	**47**

Table 33: Tentative location of EVCS for High Uptake by 2030 in Bhutan

Region	Location	No of EVCS		Total No of EVCS by 2030
		As of 2022	Additional between 2022-30	
Paro	Core area	1	3	4
	Taktsang Base	1	6	7
Punakha	Dzong parking	-	5	5
	Khuruthang	1	3	4
Thimphu-Wangdue highway	Dochula	-	4	4
	Hongtsho	-	2	2
	Menchuna	1	2	3
Wangdue	Bajo	-	4	4
	Metsina	1	3	4
Thimphu	Core area	8	5	13
	Dechencholing	1	5	6
	Tango base	1	4	5
	Buddha point	-	6	6
	Motithang Takin Reserve	-	4	4
	Khasadrupchu	1	3	4
Thimphu - Phuentsholing highway	Wangkha	2	4	6
	Taktikothi	-	4	4
	Gedu	1	2	3
Phuentsholing	Core area	2	5	7
Paro-Haa highway	Bitekha	1	2	3
Haa	Core area	1	2	3
Thimphu-Paro highway	Chhudzom	-	3	3
Total		**23**	**81**	**104**

8.5.5 CAPEX Requirement

Total investment required to install charging stations was determined based on the following assumptions:

- Although 23 QCs will be installed between 2019 and 2021 by RGoB through UNDP-GEF, the cost of these QCs was considered from 2022 for the convenience of financial analysis. It was further assumed that the cost of 23 QCs will be transferred to the QC station operator.
- Separate cost scenarios were considered for low and high uptake of EVs.
- Cost of QC is Nu 1,820,000.00 (US$ 26,000 @ US$ 1 = Nu 70). The cost was derived based on average cost of a QC, as estimated for the UNDP-GEF project.

- Constant annual inflation rate of 3% for five years.
- Each station needs a leased line internet connection @Nu 1300/Mbps, based on existing rate from the internet service provider.
- Each QC requires 5 m^2 land, but the assumption is that there is no land lease rental as it is on the government owned land.
- Installation cost of QC is the same in all districts.
- Financial analysis was done at a discount rate of 10%.

Based on these assumptions, the total present value of the capital investment required is Nu 101,333,895 (US$ 1,447,627) for low uptake and Nu 190,522,472 (US$ 2,721,749) for high uptake. The detailed CAPEX is provided in Tables 9 and 10 for low and high uptake, respectively.

The CAPEX requirement is substantial, and may not be attractive to the private companies as such a project is being undertaken for the first time in the country.

Table 34: CAPEX Requirement for Low Uptake

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 0*	**Year 1****	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
No of QCs	**22**	**24**	**27**	**29**	**32**	**36**	**39**	**43**	**47**
Charger cost	40,040,000	3,749,200	5,623,800	3,749,200	5,623,800	7,498,400	5,623,800	7,498,400	7,498,400
New electricity connection, transformer, cabling (100 meters), panels, breakers, energy meter	17,367,922	1,626,269	2,439,404	1,626,269	2,439,404	3,252,538	2,439,404	3,252,538	3,252,538
Civil works (flooring, boards, painting, brandings, shed/ cover, etc)	2,220,054	201,823	302,735	201,823	302,735	403,646	302,735	403,646	403,646
Electric Vehicle Supply Equipment (EVSE) management software - Integration with chargers and payment gateways	1,057,200	31,200	46,800	31,200	46,800	62,400	46,800	62,400	62,400
Total CAPEX (Nu)	**60,685,176**	**5,608,492**	**8,412,738**	**5,608,492**	**8,412,738**	**11,216,984**	**8,412,738**	**11,216,984**	**11,216,984**
Total CAPEX (US$)	**866,931**	**80,121**	**120,182**	**80,121**	**120,182**	**160,243**	**120,182**	**160,243**	**160,243**

** RGoB would have installed 23 QCs by 2022, so there won't be actual CAPEX on the part of BPC.*
*** From 2023 onwards, CAPEX is only for incremental increase of QCs*

Table 35: CAPEX Requirement for High Uptake

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 0*	**Year 1****	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
No of QCs	**24**	**29**	**35**	**42**	**50**	**60**	**72**	**86**	**104**
Charger cost	43,680,000	9,373,000	11,247,600	13,122,200	14,996,800	18,746,000	22,495,200	26,244,400	33,742,800
New electricity connection, transformer, cabling (100 meters), panels, breakers, energy meter	18,946,824	4,065,673	4,878,807	5,691,942	6,505,076	8,131,345	9,757,614	11,383,883	14,636,422
Civil works (flooring, boards, painting, brandings, shed/ cover, etc)	2,421,878	504,558	605,469	706,381	807,293	1,009,116	1,210,939	1,412,762	1,816,408
Electric Vehicle Supply Equipment (EVSE) management software - Integration with chargers and payment gateways	1,088,400	78,000	93,600	109,200	124,800	156,000	187,200	218,400	280,800
Total CAPEX (Nu)	**66,137,102**	**14,021,230**	**16,825,477**	**19,629,723**	**22,433,969**	**28,042,461**	**33,650,953**	**39,259,445**	**50,476,430**
Total CAPEX (US$)	**944,816**	**200,303**	**240,364**	**280,425**	**320,485**	**400,607**	**480,728**	**560,849**	**721,092**

** RGoB would have installed 23 QCs by 2022, so there won't be actual CAPEX on the part of BPC.*

*** From 2023 onwards, CAPEX is only for incremental increase of QCs*

Operating cost of the QCs was calculated based on the following baseline assumptions:

- To manage the QCs, it is recommended to employ six technicians along with a deputy manager as shown in Figure 16.
- Each vehicle charges for 30 minutes per charge, which is equal to 25 kWh of electricity consumption, given a QC is rated at 50 kW
- An EV charges at least once per day at any of the QCs
- Capital equity of 50% from the state banks at a minimal lending interest rate for a loan of 10 years
- Utilisation of QC station is 33.33%
- BPC charges the QC station the same tariff as other low voltage consumers, i.e., block tariff at Nu 1.28/kWh up to 100 kWh, Nu 2.68/kWh for 100-300 kWh, and Nu 3.53/kWh for more than 300 kWh
- The QC station will sell power at Nu 7/kWh or Nu 175/charge of 30 minutes

Based on these assumptions, the total present value of the OPEX requirement are Nu 16,071,677 (US$ 229,595) and Nu 16,262,046 (US$ 232,315) for low and high uptake, as shown in the tables below.

Table 36: OPEX Requirement for Low Uptake

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Technicians (1 technician @25k/month considered for first 6 months	150,000	154,500	159,135	163,909	168,826	173,891	179,108	184,481	190,016
Site maintenance staff (1 personnel @25k/month throughout year)	1,800,000	1,854,000	1,909,620	1,966,909	2,025,916	2,086,693	2,149,294	2,213,773	2,280,186
Network service provider fee	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006
EVSE management software fee (considered as 10% of net margin on electricity charges)	212,291	238,538	268,356	288,234	318,051	357,807	387,625	427,381	467,138
Payment gateway fee (1-2% of total money collected)	-	-	-	-	-	-	-	-	-
Land lease rental	-	-	-	-	-	-	-	-	-
Advertising	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006
Total OPEX (Nu)	**2,282,291**	**2,370,638**	**2,464,419**	**2,550,179**	**2,647,854**	**2,757,505**	**2,859,313**	**2,973,220**	**3,089,352**
Total OPEX (US$)	**32,604**	**33,866**	**35,206**	**36,431**	**37,826**	**39,393**	**40,847**	**42,475**	**44,134**
Total cost (Nu)	**62,967,468**	**7,979,130**	**10,877,157**	**8,158,671**	**11,060,593**	**13,974,489**	**11,272,051**	**14,190,204**	**14,306,336**
Total cost (US$)	**899,535**	**113,988**	**155,388**	**116,552**	**158,008**	**199,636**	**161,029**	**202,717**	**204,376**

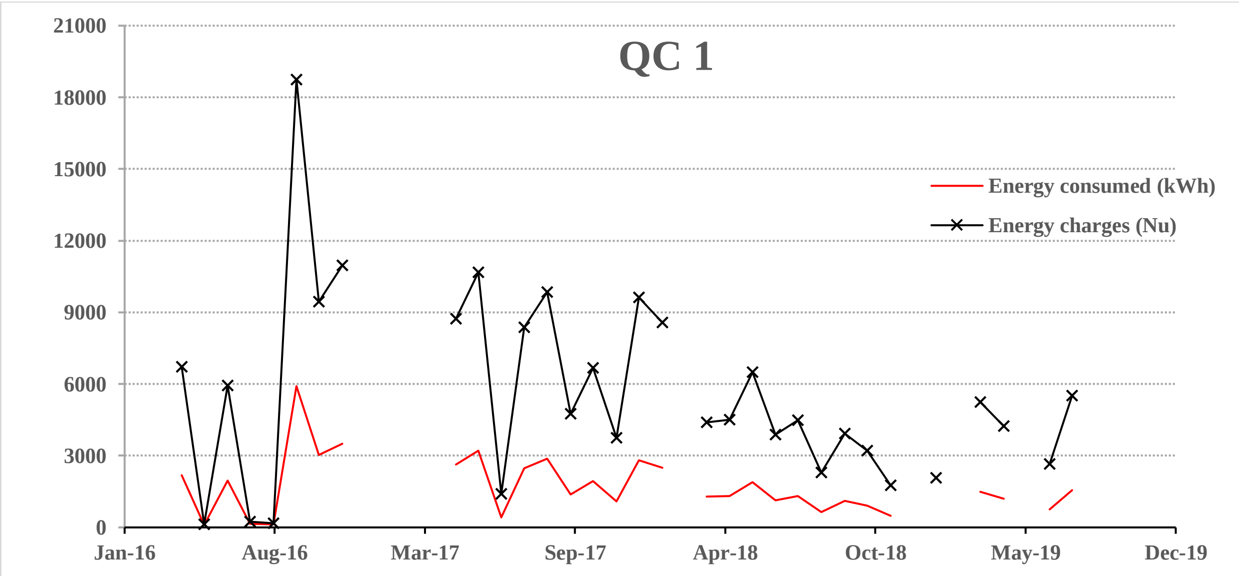
Table 37: OPEX Requirement for High Uptake

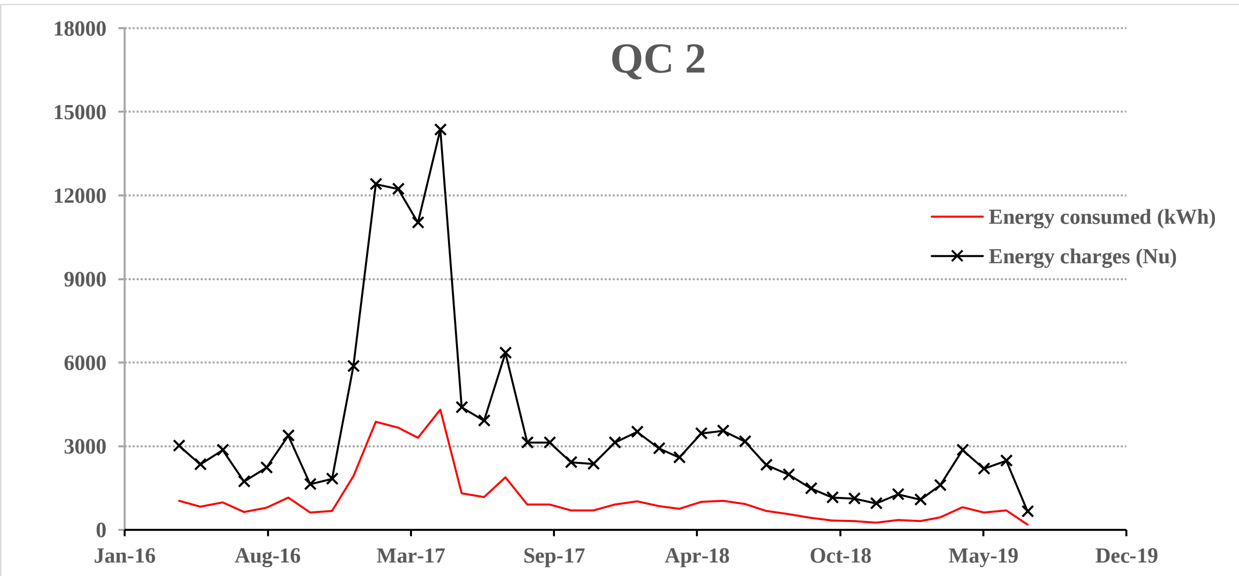
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Technicians (1 technician @25k/month considered for first 6 months	150,000	154,500	159,135	163,909	168,826	173,891	179,108	184,481	190,016
Site maintenance staff (1 personnel @25k/month throughout year)	1,800,000	1,854,000	1,909,620	1,966,909	2,025,916	2,086,693	2,149,294	2,213,773	2,280,186
Network service provider fee	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006
EVSE management software fee (considered as 10% of net margin on electricity charges)	231,591	288,234	347,868	417,442	496,955	596,346	715,615	854,762	1,033,666
Payment gateway fee (1-2% of total money collected)	-	-	-	-	-	-	-	-	-
Land lease rental	-	-	-	-	-	-	-	-	-
Advertising	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006
Total OPEX (Nu)	**2,301,591**	**2,420,334**	**2,543,931**	**2,679,387**	**2,826,758**	**2,996,043**	**3,187,303**	**3,400,601**	**3,655,880**
Total OPEX (US$)	**32,880**	**34,576**	**36,342**	**38,277**	**40,382**	**42,801**	**45,533**	**48,580**	**52,227**
Total cost (Nu)	68,438,692	16,441,564	19,369,408	22,309,110	25,260,727	31,038,504	36,838,256	42,660,046	54,132,310
Total cost (US$)	**977,696**	**234,879**	**276,706**	**318,702**	**360,868**	**443,407**	**526,261**	**609,429**	**773,319**

8.5.6 Financial Viability of a Charging Station

The existing four QC stations, installed by the RGoB, are being managed by a private company through an annual maintenance contract. The electricity bill is paid by the government at the same rate as any other low voltage consumer. EV charging is free at all the QC stations. Figure 17 shows monthly electricity consumption and bills for the past three years. The electricity bill record of two QC stations in Thimphu shows that the monthly electricity consumption averages 2278 kWh/month, which is quite low for a private firm to install and manage similar QC stations. However, from the figures it can be inferred that initially the energy demand was high and reduced after September 2017, which could be attributed to the lower number of EVs after initial kick-off between 2016 and 2017.

Figure 20: Monthly Energy Consumption and Energy Charges of Two QC Stations in Thimphu





Source: BPC, 2019

Table below shows the revenue model for low and high take, respectively. The model considered principal repayment over a 10-year loan term, 10% interest per annum and depreciation of 10% per year. Equations 1, 2 & 3 show the method used to analyse the revenue for EVCSs.

$$\text{Total revenue from power sold} = \left(\begin{array}{l} \text{No of EVs x power consumed/charge x 365 days} \\ \text{x Rate of EV using QC x EVCS power selling rate} \end{array} \right) \quad \text{Equation (1)}$$

$$\text{Margin on power sold} = \left(\begin{array}{l} \text{Total revenue} \\ \text{from power} \end{array} \right) - \left(\begin{array}{l} \text{No of EVs x Power demand per} \\ \text{charge x 365 days x Rate of EV} \\ \text{using QC x electricity tariff} \end{array} \right) \quad \text{Equation (2)}$$

$$\text{Net revenue} = \text{Margin on power sold} - \left(\begin{array}{l} \text{principal repayment/year + loan} \\ \text{interest/year + depreciation} \\ \text{amount/year + operational cost/year} \end{array} \right) \quad \text{Equation (3)}$$

Revenue Model for Low Uptake

At an EVCS utilisation rate of 33.33%, loan equity of 50% at 10% lending rate, and electricity selling rate of Nu 175/30 minutes charging, net revenue is negative in the first two years. However, net revenue increases as the EV number increases. The break-even number is approximately 587 EVs at 33.33% utilisation rate as shown in table below.

Table 38: Revenue Model for Low Uptake

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Number of EVs charged	442	486	537	587	646	711	782	860	946
Total power sold (Nu)	22,276,800	24,494,400	27,064,800	29,584,800	32,558,400	35,834,400	39,412,800	43,344,000	47,678,400
Margin on power sold (Nu)	11,042,928	12,142,224	13,416,408	14,665,608	16,139,664	17,763,624	19,537,488	21,486,240	23,634,864
EVCS Utilisation rate	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Net revenue (Nu)	**-2,119,635**	**-1,108,686**	**71,718**	**1,235,158**	**2,611,538**	**4,125,848**	**6,642,573**	**8,477,418**	**10,509,911**

The above table shows that at a discount rate of 10%, the net present value (NPV) of the investment is Nu 2,004,785 (US$ 28,640), indicating a viable business with 10% internal rate of return (IRR).

To ascertain a maximum threshold for the rate of utilisation of EVCS at the above assumptions, a sensitivity analysis was carried out as shown in Table below. NPV is negative at 32.23% utilisation of EVCS. This indicates that business may not be viable if the overall utilisation rate of EVCS is below 32.44% at stated assumptions.

Table 39: NPV Variation with EVCS Utilisation

EVCS Utilisation (%)	NPV (US$)
33.33	28,640
33.10	17,886
32.65	7133
32.44	1756
32.23	-3,620

The NPV is highly sensitive to the rate at which the EV users are charged for using the EVCS. At 33.33% EVCS utilisation, the minimum electricity selling rate should be Nu 7/kWh or Nu 175/30 minutes charging. Below this, the NPV is negative indicating that the business is not viable. The table below illustrates the variation of NPV with EVS utilisation at electricity selling price of Nu 7.5 and 8/kWh.

Table 40: NPV Variation with EVCS Utilisation

Electricity Selling Price = Nu 7.5/kWh		Electricity Selling Price = Nu 8/kWh	
EVCS utilisation rate (%)	**NPV (US$)**	**EVCS utilisation rate (%)**	**NPV (US$)**
33.33	152,599	33.33	276,558
31.39	91,084	31.39	207,296
29.30	29,570	29.30	138,034
28.88	17,267	27.21	68,772
28.46	4,964	26.37	41,067
28.04	-7,339	25.95	27,214
27.63	-19,642	25.53	13,362
27.21	-31,945	25.11	-490

At an assumed electricity selling price of Nu 7.5/kWh and 8/kWh, the minimum utilisation rate of EVCS should be 28.46% and 25.53% below which the NPV is negative. This shows that with Nu 0.5 increase in electricity selling price, the threshold EVCS utilisation rate is reduced from 33.33% to 28.46%. While the increased electricity selling price is good from a business perspective, it could have a negative impact on the uptake of EVs.

For example, it has been estimated that, on average, taxis consume 6,000 litres of fossil fuel/year (DRE, 2015). This translates to 90,000 km a year assuming 15 km/litre. Assuming an average price of both diesel and petrol as Nu 60/litre, taxis spend Nu 360,000/year on fuel alone. On the other hand, the new model EV approved by the RGoB for use in Bhutan would have a minimum mileage of 200 km/full charge. For a distance of 90,000 km, EVs need to be recharged 450 times/year at a cost of Nu 78,750/year at electricity selling price of Nu 7/kWh. This is 4.6 times cheaper than fossil fuel cost. An increase of Nu 0.5/kWh is equal to Nu 5,625/year for EV users. Given the high initial cost of EVs, it must result in substantial saving in running cost otherwise people may be reluctant to switch to EVs. Therefore, an increase in the selling price of electricity beyond Nu 7/kWh is not recommended.

Revenue Model for High Uptake

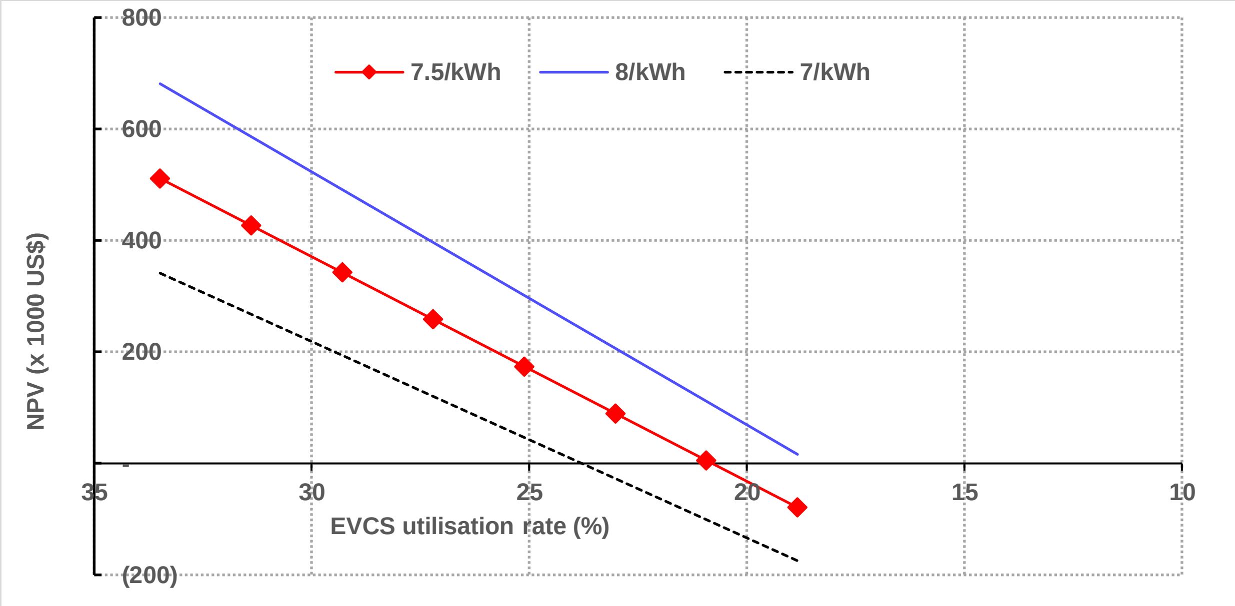
At the same EVCS utilisation rate, loan equity and lending rate, and electricity power selling rate as that of low uptake, net revenue is positive from the second year onwards. NPV of the investment at a 10% discount rate is Nu 23,893,357 (US$ 341,334), indicating a viable business with 17% IRR.

Table 41: Revenue Model for High Uptake

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Number of EVs charged	482	578	694	833	1000	1200	1440	1728	2074
Total power sold (Nu)	24,292,800	29,131,200	34,977,600	41,983,200	50,400,000	60,480,000	72,576,000	87,091,200	104,529,600
Margin on power sold (Nu)	12,042,288	14,440,752	17,338,896	20,811,672	24,984,000	29,980,800	35,976,960	43,172,352	51,816,816
EVCS Utilisation rate	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Net revenue (Nu)	**-1,139,574**	**1,140,147**	**3,914,693**	**7,252,014**	**11,276,970**	**16,104,485**	**22,754,055**	**29,736,149**	**38,125,334**

Like in the case of low uptake scenario, a sensitivity analysis was carried out, as illustrated in Figure 18, to ascertain the threshold level of EVCS utilisation. For the business to be attractive, EVCS utilisation should be 23.86% at Nu 7/kWh, 20.93% at Nu 7.5/kWh and 18.84% at Nu 8/kWh. Compared with low uptake, the EVCS utilisation rate could be much lower in high uptake.

Figure 21: Sensitivity of NPV to EVCS Utilisation Rate and Electricity Selling Price



8.5.7 Business Models for Setting up EV Charging Stations

All four QC stations were constructed by the government through a private contractor. The stations are maintained by a private enterprise through an annual maintenance contract, but the electricity bill is paid by the government to BPC. While there is no plan for privatisation of the charging stations, with the increase of EVs following an increase of QCs, it may not be sustainable post 2021. Four different business models are being explored to make EVCS sustainable and at the same time benefit EV owners/users.

Option-1: Business as usual (BAU) - The first option is to continue with the current system, i.e. the government installs EVCS, manages and provides free charging to EV users. While this option would promote and encourage the use of EVs, the initial investment and operational costs are substantial as shown in Tables 9 and 11. By 2030, the government has to invest US$ 2,211,230 and US$ 4,521,266 for low and high uptake, respectively. Under this option, the EV owners/users may be able to recover the differential cost of EV within four years and the total cost of EV within seven years based on the calculations and assumptions as follows:

i. The price of a new Nissan Leaf EV in Bhutan is US$ 32,857.

ii. Total fuel cost/year for a taxi is US$ 5,143 (Nu 360,000 for 6,000 litres/year @ Nu 60/litre of diesel/petrol). This amount is saved if EV users need not pay for charging.

iii. Cost of the commonly used car in Bhutan is US$ 10,714.

iv. Differential cost of EV = Cost of EV – (Cost of conventional car + Govt. Subsidy)
= 32,857 – (10,714 + 5,500) = US$ 16,643

v. Government will continue to provide subsidy beyond the year 2023.

vi. Payback period of differential cost is 3.2 years.

vii. Payback period of total EV cost is 6.4 years.

Table 42: Total Annual Cost of EVCS (CAPEX + OPEX)

Year	Low Uptake		High Uptake	
	Nu	US$	Nu	US$
2022	62,967,468	899,535	68,438,692	977,696
2023	7,979,130	113,988	16,441,564	234,879
2024	10,877,157	155,388	19,369,408	276,706
2025	8,158,671	116,552	22,309,110	318,702
2026	11,060,593	158,008	25,260,727	360,868
2027	13,974,489	199,636	31,038,504	443,407
2028	11,272,051	161,029	36,838,256	526,261
2029	14,190,204	202,717	42,660,046	609,429
2030	14,306,336	204,376	54,132,310	773,319

Although the EV users we talked to prefer the current system, in the long run, this option would not be sustainable. Therefore, this option is not recommended.

Option-2: The second option is similar to the first option, but the users will be charged for using EVCS at a predetermined price. The same assumptions as in option-1 were used to ascertain the EVCS utilisation rate and selling price of electricity. It was further assumed that the government will charge the EVCS users enough to recover the operational cost.

From the sensitivity analysis, it was found that the optimal electricity selling price is Nu 5/kWh, which is Nu 1.4 more than the domestic tariff. At this selling price, the net revenue earned from the EVCS would be positive even at 20% EVCS utilisation rate as shown in figure above. This figure (20%) is a conservative estimate given that EV must recharge at least 450 times in a year assuming that it covers 90,000 km/year at 200 km mileage per full charge.

Table 43: Cash Flow and Net Revenue

Year	2022	2023	2024	2025	2026	2027	2028	2029	2029
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Number of EVs charged	**442**	**486**	**537**	**587**	**646**	**711**	**782**	**860**	**946**
Total power sold (Nu)	9,945,000	10,935,000	12,082,500	13,207,500	14,535,000	15,997,500	17,595,000	19,350,000	21,285,000
Margin on power sold (Nu)	2,923,830	3,214,890	3,552,255	3,883,005	4,273,290	4,703,265	5,172,930	5,688,900	6,257,790

Year	2022	2023	2024	2025	2026	2027	2028	2029	2029
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Utilisation of EVCS	20.1%	20.1%	20.1%	20.1%	20.1%	20.1%	20.1%	20.1%	20.1%
Net revenue (Nu)	**413,309**	**607,188**	**841,395**	**1,077,808**	**1,360,650**	**1,670,010**	**2,027,686**	**2,418,358**	**2,859,503**

Under this option, the EV users have to pay only minimal charge for using EVCS. Based on the stated assumptions, the payback period for owning EV is 5.1 years for differential EV cost and 7.6 years for total cost of EV.

Table 44: Payback Period of EV

Electricity selling price (Nu/kWh)	**5**
Charging cost/annum (US$)	804
Payback period of differential EV cost	5.1
Payback period of total EV cost	7.6

The EVs that will be implemented through UNDP-GEF project has been recommended to include extended battery pack warranty to at least 400,000 kms or 5 years of operations, whichever is earlier, before the battery pack capacity reduces to 80% of its nameplate (rated) capacity[12]. By taking into account the cost of battery replacement at the end of five years or 400,000 kms, the simple payback period of EV is 8.72 years assuming average cost of battery pack replacement is US$ 5000[13,14].

While this option would be attractive to the EV users, it has the following disadvantages.

i. The government will not be able to recover the cost of EVCS installation.
ii. At the end of the life term of EVCS, the government has to spend a minimum of the same amount as today or more to install a new set of EVCS.
iii. This option doesn't encourage private sector development.
iv. EV users do not share the cost of EVCS.

Therefore, based on the above drawbacks, this option is also not recommended.

Option-3: Under the third option, the government takes the responsibility to install the EVCS and leases out to a private company or BPC to manage, operate and maintain for a fixed term with a condition that at the end of the lease period the leasee has to restore the EVCS to its original condition. This option has the

12 Gopal, K., "Proposed Technical Specifications for Electric Vehicles and Charging Infrastructure for Bhutan Sustainable Low-emission Urban Transport Systems Project", UNDP-GEF, Bhutan, April 2019.

13 https://www.zap-map.com/nissan-launches-5000-battery-replacement-scheme/

14 https://cleantechnica.com/2017/10/04/nissan-leaf-replacement-battery-will-cost-5499/

following advantages:

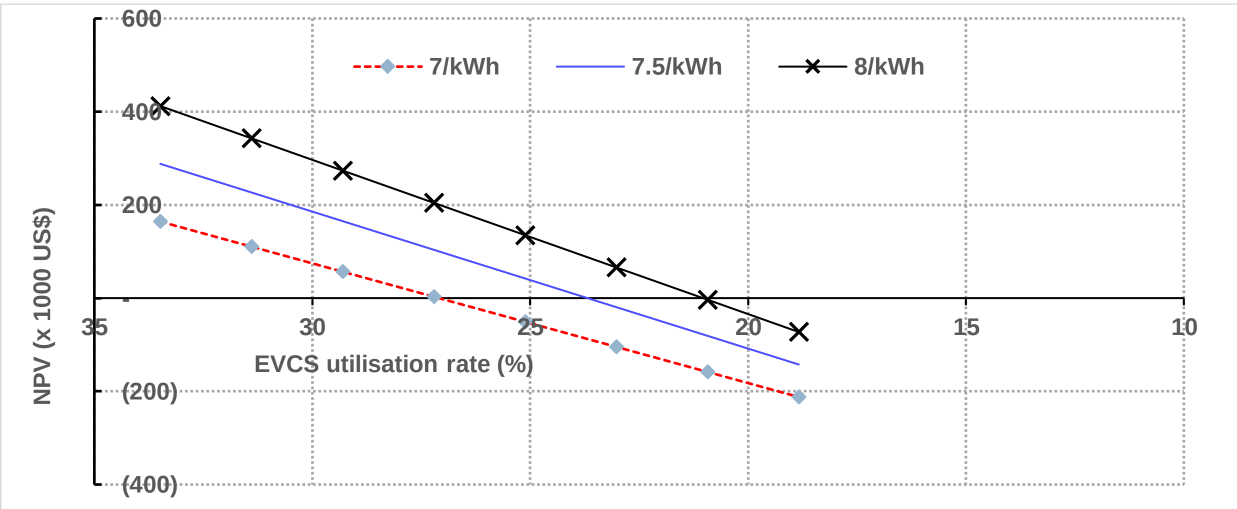
i. The government would be able to recover the cost of installation, but without the interest on investment at the end of the lease period.
ii. The government need not maintain the system and can focus on EV policy initiatives and regulations than on operating EVCS.
iii. Business risk is transferred to leasee and there is a guarantee that the government will get back the initial investment amount.

The business model also seems viable even at 27% EVCS utilisation rate and electricity selling price of Nu 7/kWh as illustrated in figure below for low uptake. At an electricity selling price of Nu 8/kWh, the EVCS utilisation rate could be as low as 21%.

Utilisation rate of EVCS is defined as number of hours of QC used within 24 hours expressed as a percentage, i.e. if EVCS is used for 8 hours in a day, then utilisation rate is 33.33%. Considering the following factors, the maximum EVCS utilisation rate in this report was assumed to be 33.33%, with the following assumptions:

- Every EV will have a home charger for which user will pay domestic tariff.
- EV users prefer slow charger to quick charger.
- The minimum mileage for a fully charged battery is 200 km, so more than one quick charging may not be required in a day.
- Taxis will not be used in the night.

Figure 22: NPV Variation with Utilisation Rate and Different Electricity Selling Price



Under this option, net revenue is positive from the second year with high NPV at 33.33% EVCS utilisation rate as illustrated below. This option seems financially feasible from both perspectives - business and the government.

Table 45: Cash Flow and Net Revenue at 33.33% EVCS Utilisation Rate

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Depreciation (US$)	144,763	144,763	144,763	144,763	144,763	144,763	144,763	144,763	144,763
Operational cost (US$)	32,604	33,866	35,206	36,431	37,826	39,393	40,847	42,475	44,134
Total cost (US$)	177,367	178,629	179,969	181,194	182,589	184,156	185,610	187,237	188,896
Cash flow (US$)	157,756	173,460	191,663	209,509	230,567	253,766	279,107	306,946	337,641
Net revenue at Nu 7/kWh (US$)	**-19,611**	**-5,169**	**11,694**	**28,315**	**47,977**	**69,610**	**93,497**	**119,709**	**148,745**
Net revenue at Nu 7.5/kWh (US$)	**3,121**	**19,826**	**39,311**	**58,503**	**81,200**	**106,176**	**133,714**	**163,938**	**197,396**
Net revenue at Nu 8/kWh (US$)	**25,852**	**44,820**	**66,929**	**88,692**	**114,423**	**142,742**	**173,931**	**208,166**	**246,047**

Table 46: Sensitivity of NPV ($ x 1000) with EVCS Utilisation Rate and Margin on Electricity Tariff

Electricity Selling Price (Nu/kWh)	Margin on Electricity Tariff (Nu/kWh)	EVCS Utilisation Rate				
		35%	30%	25%	20%	15%
4.0	**0.47**	-652	-697	-741	-786	-831
4.5	**0.97**	-479	-549	-618	-688	-757
5.0	**1.47**	-306	-401	-495	-589	-683
5.5	**1.97**	-134	-253	-371	-490	-609
6.0	**2.47**	39	-105	-248	-392	-535
6.5	**2.97**	212	43	-125	-293	-461
7.0	**3.47**	384	191	-1	-194	-387
7.5	**3.97**	557	339	122	-96	-313
8.0	**4.47**	730	487	245	3	-239
8.5	**4.97**	903	635	369	102	-165
9.0	**5.47**	1075	783	492	200	-91
9.5	**5.97**	1248	931	615	299	-17
10.0	**6.47**	1421	1079	739	397	57

The table above presents sensitivity of NPV with the EVCS utilisation rate and margin on electricity tariff. At 35% EVCS utilisation rate, NPV is positive at electricity selling price of Nu 6/kWh. Whereas at 15% EVCS utilisation rate, NPV is positive at electricity selling price of Nu 10/kWh which means Nu 6.47 more than what a domestic consumer would pay. Higher electricity selling price would not be attractive to the EV users and thus dissuade common people from switching to EV. At electricity selling price of Nu 8/kWh, i.e. margin of Nu 4.47/kWh seems reasonable with NPV of US$ 245,00 even at 25% EVCS utilisation rate.

With the same assumptions as in Option-1, the EV owners/users could recover the differential cost and the total cost of EV as shown in table below.

Table 47: Payback Period of EV

Electricity selling price (Nu/kWh)	7	7.5	8	9
Charging cost/annum (US$)	1125	1205	1286	1446
Payback period of differential EV cost	4.27	4.35	4.44	5..99
Payback period of total EV cost	9.42	9.61	9.81	10.24

Option-4: The fourth option is to build and operate by the utility company or through Public Private Partnership (PPP). In this option, the utility company or through PPP will invest in EVCS, operate, collect charging fee from the users and upkeep the EVCS. In order to avoid an exorbitant electricity selling price, the government has to prefix the price at an admissible rate which benefits both the operator and the EV users. Considering the following assumptions:

i. Loan equity of 50% from the state bank.
ii. The maximum utilisation rate of EVCS is 33.33%, which is reasonable given that EVs need to charge at least 450 times in a year.
iii. All other assumptions are the same as in option-1

For the above stated assumptions, the feasibility of the EVCS business will depend on the bank loan lending rate. Therefore, a sensitivity analysis was carried out to ascertain the optimal lending rate at which the EVCS business is feasible as illustrated in table below.

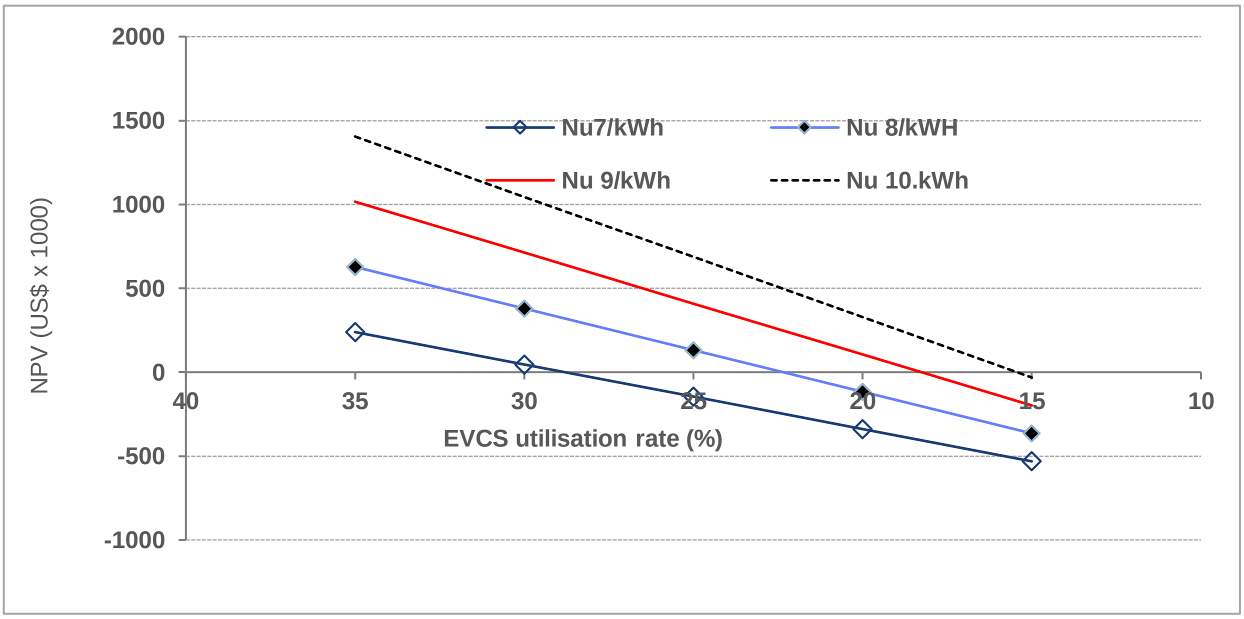
Table 48: Sensitivity of NPV ($ x 1000) at 33.33% EVCS Utilisation Rate with Margin on Electricity Tariff and Loan Interest

Electricity Selling Price (Nu/kWh)	Margin on Electricity Tariff (Nu/kWh)	Loan Interest Rate					
		5%	6%	7%	8%	9%	10%
7.0	**3.47**	259	244	229	213	197	181
7.5	**3.97**	445	430	414	399	383	366
8.0	**4.47**	630	616	600	585	569	552
8.5	**4.97**	816	801	786	771	755	738

Electricity Selling Price (Nu/kWh)	Margin on Electricity Tariff (Nu/kWh)	Loan Interest Rate					
		5%	6%	7%	8%	9%	10%
9.0	**5.47**	1002	987	972	956	940	924
9.5	**5.97**	1188	1173	1158	1142	1126	1110
10.0	**6.47**	1374	1359	1344	1328	1312	1296

At 33.33% EVCS utilisation rate and electricity selling price of Nu 7/kWh, NPV over the project period is US$ 259,000 and US$ 181,000 at bank lending rate of 5% and 10%, respectively, indicating that the investment is worthwhile at either of the bank lending rates. However, this option is risky if the EVCS utilisation rate falls below 33.33% as shown in figure below. Even at 25% EVCS utilisation rate and Nu 8/kWh electricity selling rate, NPV is $ 131,000 only which is unlikely to be attractive as a business model. Therefore, the recommended minimum electricity selling price in this option is Nu 9/kWh.

Figure 23: NPV Variation with Utilisation Rate and Different Electricity Selling Price



Risks in EVCS Business

One of the main risks of EVCS business is the lack of EV users coming to use QCs. With every EV having a HC and preference of slow charging to fast charging, business is dependent on the number of EV users using QCs and frequency of use. The other risk is change in technology of charging. If the car manufacturer or EV regulators change the standard and type of EVCS, then the current EVCS would be invalid and cost of switching to new type and standard would be substantial.

Summary of Business Models

The proposed business models can be summarised as follows:

i. Although option-1 could promote and encourage people to switch from a conventional vehicle to an EV, as there is potential for substantial saving in fuel cost, it is not recommended as this option would not be sustainable in the long run.

ii. Under option-2, EVCS users have to pay a minimal price but the government will not be able to recover the investment. Therefore, it is also not recommended.

iii. Under option-3, the government does not have any risk and will also be able to recover the investment at the end of the lease period. Therefore, this option is recommended as a good business model.

iv. The last option to invest and operate by utility company or through PPP also seems to show a reasonably good business perspective. But there is associated risk of failure if the EVCS utilisation rate is below 33.33% and the banks charge a high lending rate. Therefore, this option could be pursued with caution.

Table 49: Summary of Business Model Options

Business Model	Initial Investment	Operation & Maintenance	Electricity Selling Price (minimum)	EVCS Utilisation Rate (minimum)	Remarks
Option-1	Government	Government	Free	-	Not recommended
Option-2	Government	Government	Nu 5/kWh	21%	Not recommended
Option-3	Government	Private/utility company	Nu 8/kWh	25%	Most sustainable option
Option-4	Utility company or through PPP	Utility company or through PPP	Nu 9/kWh	25%	Risky option

Costs associated with a distribution company

From the analysis of the impact on the existing distribution network, it is clear that the installation of EVCS will have a minimal impact on the utility distribution network till 2030. Therefore, there is no additional investment required on transmission and distribution network.

For utility company to invest and operate EVCS business, the total cost over 9 years is Nu 154,786,099 (US$ 2,211,230) and Nu 316,488,617 (US$ 4,521,266) for low and high uptake, respectively. The detailed cost is shown in table below.

Table 50: Detailed CAPEX and OPEX over 9-years Period

Year	Low Uptake		High Uptake	
	CAPEX (Nu)	OPEX (Nu)	CAPEX (Nu)	OPEX (Nu)
2022	60,685,176	2,282,291	66,137,102	2,301,591
2023	5,608,492	2,370,638	14,021,230	2,420,334
2024	8,412,738	2,464,419	16,825,477	2,543,931
2025	5,608,492	2,550,179	19,629,723	2,679,387
2026	8,412,738	2,647,854	22,433,969	2,826,758
2027	11,216,984	2,757,505	28,042,461	2,996,043
2028	8,412,738	2,859,313	33,650,953	3,187,303
2029	11,216,984	2,973,220	39,259,445	3,400,601
2030	11,216,984	3,089,352	50,476,430	3,655,880

8.5.8 Organisational Capacity Planning

Bhutan Power Corporation (BPC) with the vision "*To be innovative and efficient power utility driving the socio-economic transformation of Bhutan*"[15] is the only utility company responsible to operate and maintain the power transmission and distribution networks in Bhutan. And their mission is "*To provide affordable, adequate, reliable and quality electricity services to customers*". BPC is a Nu 30 billion company with more than 2500 employees and a strong balance sheet. So, it is well suited to invest in EVCS infrastructure as it would have access to low-cost capital, skilled human resource, experience of large-scale projects, and in-house training division. Currently, the EV project is managed by a separate Project Management Unit (PMU) under the Ministry of Information and Communications (MoIC). The existing EVCS is managed by the MoIC through a private company who is responsible for upkeep of the system. The EV users need not pay any fees for using EVCS. This modality may not be sustainable in long run as the number of EV increases.

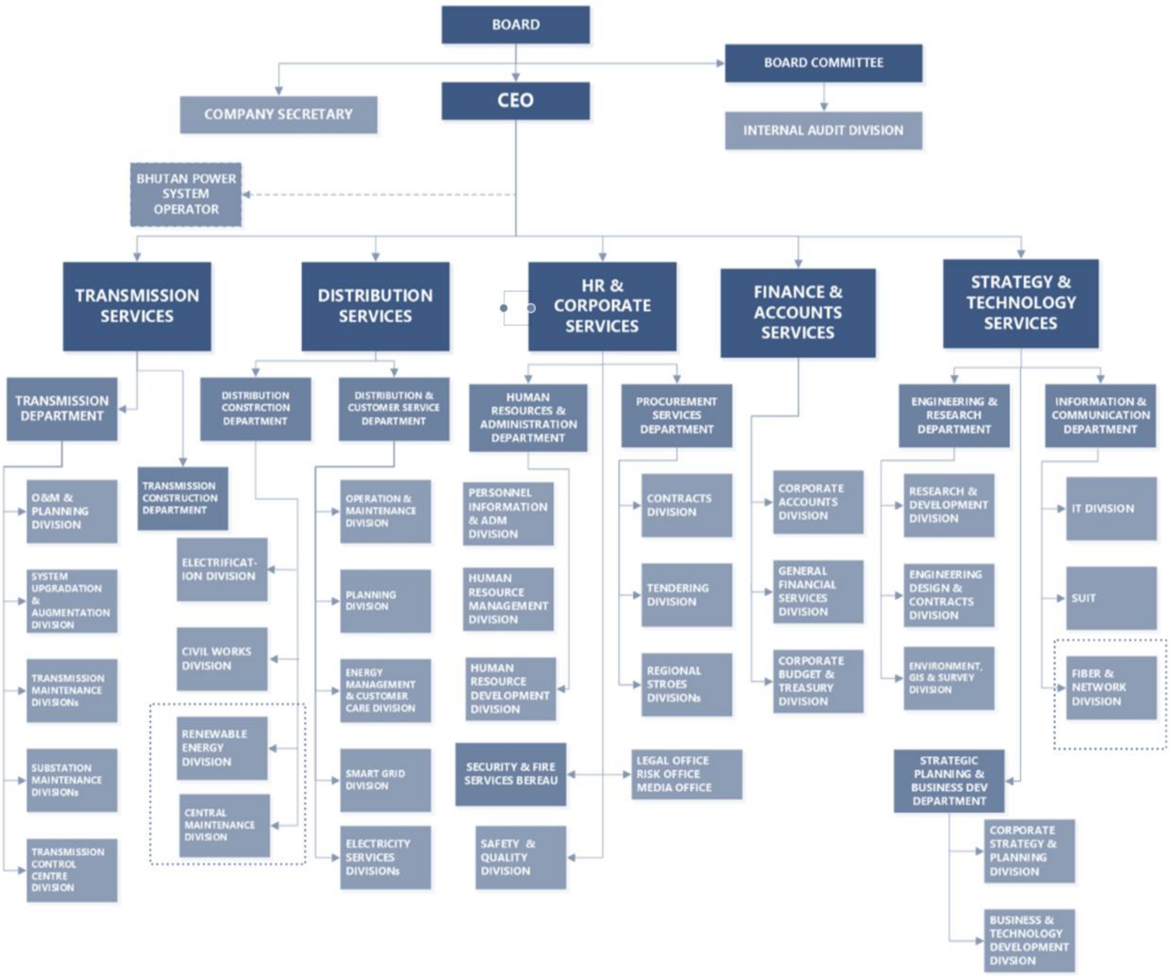
As the EV deployment grows in next few years, the number of home chargers (HC) will also increase. The unprecedented increase of HCs could lead to uncertainty regarding the residential power demand. If EVCS infrastructure is owned and operated by utility company then, it would be able to manage peak demand due to QCs and HCs, modulate the power flows between the grid and EVCSs to help balance electricity supply and demand, regulate standard and type of EVCS in the country, and utility regulators will be able

[15] https://www.bpc.bt/vision-mission/

to fix the price of energy sold to the EV users.

EVCS installed by RGoB through the UNDP-GEF project may be transferred to BPC by 2022. The current organisational structure of BPC is illustrated in figure below.

Figure 24: Current Organisational Structure of BPC[16]

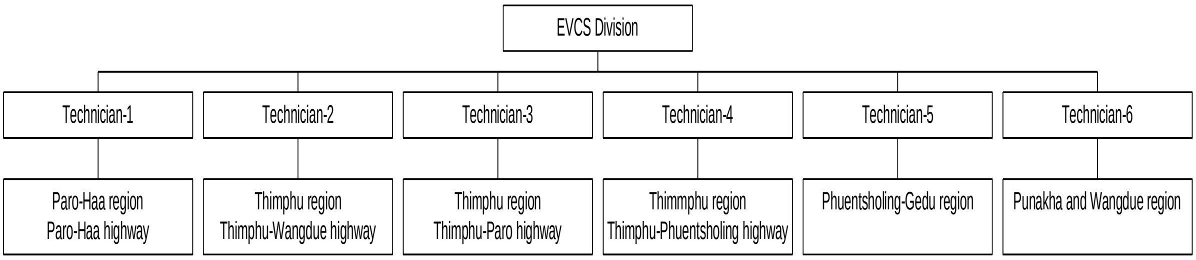


Source: BPC, 2018

In case if BPC decides to venture into EVCS infrastructure or Royal Government mandates BPC to be involved, then there is a need to create a separate division under the Distribution and Customer Service Department of Distribution Services. In order to operate and manage EVCS business, 7 additional staff are required. The number of staff is considered based on the number of EVCS, and distance between the EVCS. The proposed organisational structure is illustrated in Figure 16. The additional staff will be responsible for upkeep of the system in their respective regions.

[16] https://www.bpc.bt/organogram/

Figure 25: Proposed Organisational Structure of EVCS Division



As the BPC is not involved in implementing the current EV taxi project, the staff have limited or no experience of operation and maintenance of EVCS. Therefore, incase if BPC decides to take up EVCS business, then it has to invest in training human resource to operate and maintain EVCS. The current pool of BPC staff is involved in delivering the mandated services to the consumers.

Technical Capacity of Utility Network for EVCS

As stated earlier, EV project is managed by a separate Project Management Unit (PMU) under the Ministry of Information and Communications (MoIC). A Sr official of the utility is a member of the EV technical committee. Apart from participating as a member, the utility has no role in current EV project. To the utility, EVCS is like any other consumer and so far, it has not been not an issue either at the grid level, or a peak demand. Infact, there has not been any reports of impact to the grid that can be directly attributed to EVCS. However, utility is being proactive in planning for increased EV deployment and assessing grid capacity, and at the same time participating in EV project as a technical committee member.

From the modelling and simulation of Thimphu Distribution Network till 2030, the utility grid can accommodate the EVCS projected in this report. The state of transmission and distribution grid infrastructure is quite strong and it is evident that infrastructure upgrades will not be required. Moreover, the utility is in the process of establishing Distribution Management System (DMS) in Thimphu and drafting SMART GRID master plan for whole Bhutan. With the implementation of DMS and SMART GRID in next few years, the utility seems to be prepared for EVCS infrastructure in the network.

However, as the deployment of EV increases and with the preference of slow charging to fast charging, it is likely that HC will impact the peak load of the distribution network. The utility will need to offer and promote appropriate tariff structures to customers to encourage the shifting of EV charging loads to off-peak hours. This will not only minimize grid impacts, but reduce costs for electric vehicle owners, and at the same time defer the need for grid upgrades.

8.5.9 Challenges and Barriers

The barriers and challenges that is likely to impede the utility to involve in EVCS business.

- **Exorbitant land price:** Currently, there is no issue with the land as EVCS is owned and operated by the government. Urban environments are usually congested and relatively unplanned. With most urban land already built up and devoted to other use, finding appropriate sites for charging infrastructure where vehicles could be parked for the duration needed to charge can be challenging. If the land needs to be leased from private owners, then the urban land is very expensive and it will increase the electricity selling price. As a consequence, EV users may be dissuaded from using QCs.

- **Up-front cost of EVCS:** The cost of QC is quite significant and could present a significant barrier to charging infrastructure deployment for the utility. Taking loan from the financial institutes will further increase the electricity selling price to EV users. As a consequence, EV users may be dissuaded from using QCs.
- **Lack of trained technicians for EV charging infrastructure installation and maintenance:** For the projected EV, six technicians will be required for installing and maintaining EV charging infrastructure. As the utility has no experience of running EVCS, it needs to train the technicians.
- **Business viability:** One of the motivating factors to shift from conventional ICE cars to EV is free charging provided by the government. Unless the government allows the utility to charge the EV users for using EVCS, the utility may not be keen to take up EVCS. On the other hand, if EV users are charged for using EVCS, then this may dissuade EV users from using EVCS.

8.5.10 Concluding Remarks

From the current trend of EV deployment, it is unlikely that environmental benefits alone will convince the public to switch to EV unless supported with strong cost benefits over ICE. A modest deployment of EV was projected till 2030. While the utility has not been involved in implementation of EV and associated infrastructure so far, it is prepared and can accommodate EVCS infrastructure till 2030. From modelling and simulation of Thimphu Distribution Network, no additional investment is required to support EVCS infrastructure. Thus, there is no any pressing issues to the utility for the planned deployment of EV in the country.

It is concluded that while the utility is technically ready for EVCS, it has no or limited experience of operation and maintenance of EVCS infrastructure. Therefore, in case if utility decides (or the government mandates it to do so) to venture into EVCS, then, it need to invest in human resource. If at all, the utility decides to venture into EVCS infrastructure, then the most viable business model is Option-4. In this option, electricity selling price is recommended at Nu 8/kWh. However, this may dissuade public from switching to EV as free charging seems to be one of the motivating factors.

9 Country in Focus: India

9.1 Present EV Sales and Charging Infrastructure

The EV market in India is nascent and small with respect to other nations, both in terms of EV market acceptance and industry dynamics. The country still does not have any significant EV charging infrastructure and demand is mostly driven by policy incentives. Although the government has rolled out several benefits, EV acceptance is yet to percolate through the "price sensitive" Indian consumer. EV sales stand at less than 1% and domestic original equipment manufacturers (OEMs) are only starting to launch EV models. Such offerings are both priced higher (despite government subsidies) and show lower performance. Technology adoption is slow and local manufacturing of EV components (batteries, electric powertrains) is almost non-existent.

In fiscal 2019, total EV sales crossed 0.75 million, with electric three-wheelers comprising ~83% and electric two-wheelers accounting for close to 16%. Four-wheeler EV sales continued to linger at ~3,600 in fiscal 2019. Only two domestic manufacturers are invested in the EV space - Mahindra Electric and Tata Motors. Owing to high initial costs, global manufacturers have been bringing models through completely built units (CBUs), leading to high prices and poor sales.

Table 51: EV Population and Sales in India for 2019

Vehicle type	Population in FY19	Sales in FY19
E rickshaw[17]	1,509,259	450,000
E autos	100	100
2-W	227,250	126,000
Cars & UVs	5,039	3,600
Bus	610	500
Total	**1,742,258**	**580,200**

Source: Society of Manufacturers of Electric Vehicles

In order to address the challenges pertaining to EV adoption in the country, the Government of India (GoI) had announced several schemes and policies (discussed in the next section). In 2017, the Indian automotive industry had released a white paper, proposing a pathway towards all-new vehicle sales being electric by 2047 and 100% of intra-city public transport as all electric by 2030. However, with hardly any charging infrastructure in place, OEMs are sceptical about investing in EV manufacturing in the country. A framework for India's charging infrastructure is being worked upon by the Ministry of Power and is

[17] E-rickshaws are non-motorised, smaller e-autos which ply majorly as an alternative to hand-held and cycle-rickshaws

expected to be released in 2019. This is expected to be a key monitorable for all EV stakeholders in the country.

EV charging stations are sparse in the country and have mostly been set up for incubation and pilot purposes. There are ~350 charging stations in India; highest concentration being in the Delhi-NCR region.

Table 52: Number of Charging Stations in India (state-wise)

State	No. of Slow AC Chargers	No. of Fast DC Chargers
Delhi	141	83
Andhra Pradesh	20	29
Jharkhand	15	7
Gujarat	10	2
The Andaman and Nicobar Islands	8	4
Telangana	8	2
Madhya Pradesh	3	2
Maharashtra	2	2
Uttar Pradesh	2	1
Total	209*	132

**Note: Does not include charging networks set up by private entities like Ola Electric-32, Ather Energy- 35*

Some of the companies that have set up EV charging stations in the country are given below:

Table 53: Companies and Charging Station Portfolio in India

Companies	No. of Operational Charging Stations	No. of Planned Charging Stations
EV Motors India	1	6,500 (long term plan)
Magenta Power	32	450 (by next two years)
Ola Electric	32	100
Ather Energy	35	200 (by 2019)
Fortum India	36	700 (by 2020)
Energy Efficiency Services Ltd (EESL)	55	1000 (next three years
Tata Power	3	100 (in short term)

Several international firms such as ABB, Fortum, and Panasonic have been eyeing the Indian EV charging stations market and have lined up investments in the space. Many public sector firms such as Indian Oil Corporation Ltd (IOCL), Hindustan Petroleum Corporation Ltd (HPCL), Energy Efficiency Services Ltd (EESL) and BSES Rajdhani Power Ltd (BRPL) are also tying up with private players to enable charging infrastructure expansion. This bodes well for the country and is likely to be an opportune market in the near future, if federal policy measures are conducive. The government has made a budgetary allocation of INR 100,000 million for the second phase of the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME-II) scheme, of which INR 10,000 million have been earmarked to develop charging infrastructure in the country. The amount is to be utilised over fiscals 2020- 2022.

The following projects/proposals for establishment of charging infrastructure have been undertaken under the FAME II scheme:

Table 54: Ongoing Projects/ Proposals for EV Charging Stations in India Under FAME II Scheme

Sr. No.	Name of the Project/Proposals	Implementing Agencies
1	Fast charging public infrastructure network for EVs in Bangalore	M/s Mahindra Reva Electric Vehicles Pvt Ltd, in collaboration with Lithium Urban Technologies Pvt Ltd
2	Proposal to set up solar-based charging infrastructure for EVs in the NCR	Rajasthan Electronics & Instruments Ltd (REIL), Jaipur
3	Proposal to set up solar-based charging infrastructure for EVs in the premises of the Udyog Bhawan	Bharat Heavy Electrical Ltd (BHEL)
4	Proposal to set up 200 charging stations in the NCR (Delhi, Jaipur and Chandigarh)	Rajasthan Electronics & Instruments Ltd (REIL), Jaipur
5	Setting up of solar-based charging stations along the Delhi-Chandigarh-Delhi highway	Bharat Heavy Electrical Ltd (BHEL)
6	Setting up of charging stations along Delhi-Jaipur-Delhi highway and in Mumbai-Pune-Mumbai Expressway	Rajasthan Electronics & Instruments Ltd (REIL), Jaipur

9.2 Regulations and Federal Policies Driving EV Adoption

The Government of India (GoI) has announced several schemes and policies for the promotion of EV in the country, and these are given below:

1. *NEMMP:* The National Electric Mobility Mission Plan, launched in 2013, was one of the earliest policy initiatives taken by the Indian government to bring in a transitional shift in the country's transportation industry. Electric and hybrid mobility was encouraged to grow using several policy levers such as doling out demand side and supply side incentives for EV acquisition and manufacturing. The first phase of the FAME scheme was launched as a subset of the NEMMP programme, with an initial outlay of Rs 75 crore. The scheme intended to catalyse market development (demand generation, technology development, pilot projects and charging infrastructure) for creation of an EV ecosystem.

2. *FAME-II:* The second phase of the FAME was rolled out in March 2019 with an outlay of INR 100,000 million over a period of three years. About 85% of the outlay would be used as a demand incentive

applicable to buses, passenger vehicles and three-wheelers registered for commercial usage and public transport, along with privately owned two-wheelers. The FAME-II intends to support 1 million two-wheelers, 0.5 million three-wheelers, 55,000 four-wheelers, and 7,000 buses that operate on lithium-ion batteries or other electric power-trains. Unlike other developed countries, where incentives are mostly focused on the personal vehicle segment, the FAME-II stresses on two-wheelers and three-wheelers, which are popular and affordable. As much as 10% of the outlay (INR 10,000 million) is earmarked for charging infrastructure and the rest for administrative expenses and advertising.

3. *Amendments to model building by-laws:* The Town and Country Planning Organisation under the Ministry of Housing and Urban Affairs (MoHUA) has amended the model building by-laws (MBBL) to take into consideration the requirement to have provision for electric vehicle charging infrastructure in residential and commercial buildings. It details mandated parking provisions for EVs, additional load requirement and minimum requirement of chargers.

Table 55: Charging Infrastructure Requirements for Self-use

Building type	Plotted house
Ownership of station	Private
Connection and metering	Domestic meter
Type of charger	Slow chargers (SCs) as per the owner's specific requirements
Model of charging	AC (single)
Norms of provisions	Minimum one slow charger and additional provisions as per the owner

Source: Policy documents

Table 56: Charging Infrastructure Requirements for Commercial Use

<table>
<tr><td>Building Type</td><td colspan="4">Plotted house</td></tr>
<tr><td>Ownership of station</td><td colspan="4">Service provider</td></tr>
<tr><td>Connection and metering</td><td colspan="4">Commercial metering and payment</td></tr>
<tr><td>Type of charger</td><td colspan="4">As per minimum requirements specified in the Ministry of Power (MoP) guidelines</td></tr>
<tr><td>Additional chargers</td><td colspan="4">Public charging station (PCS) service provider shall install additional number of kiosks/ chargers beyond the minimum specified requirements to meet the ratio of charging points as prescribed below</td></tr>
<tr><td rowspan="2">Norms of provisions for charging points</td><td>4-wheelers</td><td>3-wheelers</td><td>2-wheelers</td><td>PV (buses)</td></tr>
<tr><td>1 SC – each 3 EVs, 1 fast charger (FC) – each 10EVs</td><td>1 SC – each 2 EVs</td><td>1 SC – each 2 EVs</td><td>1 FC – each 10 EVs</td></tr>
</table>

Source: Policy documents

4. *Guidelines for EV charging stations:* The MoP has announced guidelines and standards for development of EV charging infrastructure in India. According to MoP, at least one charging station must be available in a grid of 3 km X 3 km and at every 25 km on both sides of highways/ roads. The tariff for supply of electricity to EV public charging stations should not exceed 15% of average cost of supply (ACOS) in the respective state. The norms governing charging models are given in table below.

Table 57: Charger Model Standards (India)

Charger Type	Charger Connectors	Rated Voltage (V)	No. of Charging Points/ No. of Connector Guns
Fast	CCS (min 50 kW)	200-1000	1/1 CG
	CHAdeMO (min 50 kW)	200-1000	1/1 CG
	Type-2 AC (min 22 kW)	380-480	1/1 CG
Slow/ Moderate	Bharat DC-001 (15 kW)	72-200	1/1 CG
	Bharat AC-001 (10 kW)	230	1/1 CG

Note: CHAdeMo: Charge de move; CCS: Combined charging system
Source: Policy documents

As per the guidelines, the Indian government plans to roll out EV charging infrastructure in two phases. In the first phase, setting up charging infrastructure in megacities with over 4 million population will be fast tracked over the next three years. In the second phase, state capitals and Union Territory headquarters will be covered over three-five years for demonstrative effect.

5. *Reduction of taxes for EVs and spare parts:* The Central Board of Indirect Taxes and Customs (CBIC) has lowered customs duty on import of EV components to 10-15% from 15-30%. The government also slashed applicable Goods and Services Tax (GST) on lithium ion batteries from 28% to 18%. On EVs, the GST has been slashed to 5% from 12% in order to bolster market sentiment and sales.

6. *Focus on domestic manufacturing of EVs:* In order to encourage vehicle manufacturers to produce EVs in the country, the government plans to raise custom duties on EV parts and batteries in a phased manner. As part of the phased manufacturing program (PMP) of the Department of Heavy Industries, basic customs duties on completely built units of electric buses and trucks will be doubled from 25% to 50% from April 2020. Further, basic custom duty on lithium ion cells will be increased to 10% from April 2021 onwards from a present 5%. EV parts such as AC and DC chargers, motor controllers and power control units shall be taxed at 15% from 2021 as per the department’s notification on the PMP.

Table 58: Custom Duties Proposed on EV Parts

Item Description		Current BCD	Proposed BCD	Proposed Date of PMP
CBU	Bus, trucks		25%	April 2020 onwards
SKD	PV, 3W	15%	30%	
	2W		25%	
	Bus		25%	
	Truck		25%	
CKD	Bus, PV, 2W, 3W, Truck	10%	15%	
Lithium ion cells		5%	10%	April 2021 onwards
Battery Packs		5%	15%	
Parts for use in manufacture of EVs AC/ DC charger, AC/ DC motor, power control unit, energy monitor, contactor, brake system, electric compressor		0%	15%	April 2021 onwards

Note: CKD: Completed knocked down, SKD: Semi-knocked down, CBU: Completely built units

Source: Department of Heavy Industries notification dated March, 2019

7. *De-licensing EV charging station operations:* The MoP has clarified that no licence is required to operate EV charging stations in the country. In order to distribute power, a distributor licence is required from respective state electricity regulatory commissions (SERC) as per the Electricity Act 2003. The Act stipulates that sale of electricity can be carried out only by licensed electric utilities, and their franchisees/ licensees. However, the MoP contested than an EV charging station is not involved in transmission or distribution and the electricity is consumed at the charging station premises itself. Therefore, EV charging station is considered as a service and not selling electricity. Thus, the government abrogated the requirement of a licence to operate an EV charging station.

8. *Subsidy support for setting up EV charging stations:* The Indian government plans to offer subsidy support to states for deployment of 5,000 EV charging stations in cities and highways. Separate expressions of interest (EoIs) will be floated for cities and highways. The Department of Heavy Industries has already issued EoIs for setting up of 1,000 public charging stations in cities. The cities that come under the programme are: *a)* Cities with more than a million population as per 2011 Census; *b)* smart cities as notified by the MoHUA; *c)* satellite towns connected to seven metros – Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Bangalore and Ahmedabad; *d)* major cities of special category state/UTs; and *e)* the capital cities of all states/UTs not covered in the above categories. The ministry is expected to issue the EoI for highways soon. The charging stations in cities are to be built across

various locations, divided into three categories. The first category (Category A) is commercial establishments such as petrol pumps, malls, and market complexes. The second category (Category B) is state or central government establishments such as offices of public sector companies. And the third (Category C) covers semi-restricted establishments such as housing complexes. For securing subsidy for deployment of charging stations within cities, states, through their nodal agencies, will have to submit their proposals to the department. Companies willing to set up charging stations will be eligible for subsidies covering 50-100% of the costs, based on location and category as stated below:

Category A: 70% of the cost of EVSE

Category B: 100% of the cost of EVSE

Category C: 50% of the cost of EVSE

For setting up EV charging stations along highways, 100% subsidy will be given to EVSE, including cost of chargers, as per industry sources. Additionally, only central public sector entities can submit proposals for setting up charging stations along highways.

9. *Subsidy support for electric buses:* The Ministry of Heavy Industries (MHI) has issued an EoI to invite proposals from states, government departments, transportation departments, and municipal bodies for procurement of 5,000 electric buses across 55 cities. The central government will offer subsidy worth INR 25,000 million in order to bring down the upfront vehicle costs. The minimum number of buses mandated under each category are as follows:

Table 59: Number of E-buses Sanctioned (city-wise)

Category of City	Minimum Number of Buses	Number of Target Cities	Number of Cities to be Selected	No of Buses Planned to be Sanctioned
4 million plus cities	300	8	5	1,500
1 million plus cities	100	45	20	2,000
Special category of states	50	20	10	500
Other cities	50	50	20	1,000
Total			55	5,000

Eighty-six proposals from 26 states/UTs for the deployment of 14,988 e-buses were received. After evaluation of these proposals as per EoI, the Government sanctioned 5,095 electric buses to 64 Cities/ State Transport Corporations for intra-city operation, 400 electric buses for intercity operation and 100 electric buses for last mile connectivity to Delhi Metro Rail Corporation (DMRC).

The charging infrastructure, including cost of charging equipment required, necessary transformer and other civil cost for installation of required charging infrastructure for buses have to be incurred by the operator/OEM.

Furthermore, different states have brought out EV policies under which fiscal incentives and non-fiscal incentives (waiver or reduction in road taxes, toll tax, parking fees, registration charges, etc.) have been announced.

9.3 Outlook on EV Sales

The EV market in India is in its nascent stage. However, going forward, EV penetration is expected to deepen. Although the NITI Aayog (policy think tank of the Government of India) is pushing for 30% penetration by 2030, it seems to be over-optimistic. The biggest chunk of EVs will be two- and three-wheelers. Further, government companies and cab aggregators, such as Ola and Uber, are expected to pioneer EV adoption in the four-wheeler category.

As the enabling environment for electric two-wheeler (e-2W) adoption seems favourable in the medium term, we compared the cost of ownership of an e-2W with that of an internal combustion engine (ICE) motorcycle and scooter. Lower battery prices in fiscal 2024 are likely to make cost of acquisition for e-2W more favourable than current levels. In the case of e-scooters, while the cost of acquisition will be marginally more favourable in fiscal 2024, their cost of ownership is expected to slightly inch up due to lack of subsidy. On the whole, the lower battery cost is expected to offset the lack of the FAME subsidy and it will help maintain the competitiveness of e-scooter against its ICE counterparts.

Currently, supply issues, range anxiety and lack of large presence of OEMs are hindering EV adoption. We expect these to ease by fiscal 2024. As per study author estimates, by fiscal 2024, ~15% of the domestic two-wheeler sales will be e-2Ws, largely driven by scooters. The scooter segment accounts for ~34% of two-wheeler sales now and has a higher urban penetration of around 65%. Motorcycle demand is largely driven by rural customers. Major OEMs are already in the process of developing EVs in-house or acquiring stakes in EV start-ups in order to diversify their offerings. Beyond fiscal 2024, scooters will predominantly shift to EVs while motorcycles below 125 cc will begin conversion, majorly in the urban and semi urban regions owing to conducive economics.

In the four-wheeler segment, as per study author estimates, electric passenger vehicles (e-PV) are expected to account for ~4% of domestic sales by fiscal 2024, led by higher adoption within the commercial use segment. The FAME-II subsidy is only for commercial use and no benefits are provided to personal car owners. Presently, the cost of acquisition (COA) of EVs for cab aggregators are lower compared with diesel (~4% lower) or CNG (~2% lower) alternatives (taking into account battery life of 5 years, battery capacity of 16.5 kWh and present FAME subsidies of Rs. 115,336 for commercial 4W EV). The Total Cost of Ownership (TCO) for both are also lower due to increased running of vehicles in the cab aggregator segment

(~28% lower than diesel variants and ~10% lower than CNG variants). In fiscal 2024, the COA and TCO will be lower for BEVs compared with diesel and CNG variants. The lower battery cost is expected to offset the lack of the FAME subsidy and it will help maintain the competitiveness of BEVs against diesel and CNG variants for cab aggregators. The taxi segment accounts for ~10-15% of sales within passenger cars. Within the taxi segment, cab aggregators are expected to lead EV adoption. We estimate ~25% of EVs in the taxi segment will be with cab aggregators in fiscal 2024 (provided adequate infrastructure is available). At present, the TCO of electric cars for personal use is ~30% higher than a petrol variant and COA ~18% (after considering subsidy benefits towards 4W EV under FAME scheme), due to their lower running. Thus, EVs are not a viable alternative for personal use. In fiscal 2024 too, the comparable costs would remain high for EVs. As such, electric four-wheelers are not viable for adoption in the personal car segment. Thus, the share of EVs in the total passenger car sales is expected to remain low at ~4% in fiscal 2024 (~0.1% as of fiscal 2019). Beyond fiscal 2024, the commercial segment is expected to shift majorly to electric while the personal segment will start showing improved traction towards EV due to lowering cost, improved economics, better products in the market and change in consumer preferences.

In the 3W segment, significantly strong traction towards push in EV is expected due to better running cost advantage (autos ply ~100 km daily, making running costs of electric auto much lower than a conventional or CNG based auto). EV sales in the segment are expected to rise to ~43%-48% of total segmental sales by FY24 and ~70% in fiscal 2030. Further, with government push, a potential scrappage policy will drive electric adoption.

Buses and LCVs are expected to be laggards, due to higher upfront costs and lesser TCO advantage. Electric bus adoption will be driven by State Transport undertakings (STUs), which will be mandated to buy E-buses by the government going forward. Going forward, adoption is expected to rise led by subsequent procurement schemes by the government.

LCV segment will show gradual shift to EVs with rise in diesel prices, however not more than 10% of yearly sales is expected to emanate from EVs from this segment by fiscal 2030.

Table 60: Outlook on EV Sales in India

Vehicle Type	FY19	FY24	FY30
E rickshaw	450,000	875,391	985,832
3W	100	296,733	931,510
2-W	126,000	3,497,211	13,168,198
Cars & UVs	3,600	176,042	1,299,852
Bus	500	4,557	42,713

Vehicle Type	FY19	FY24	FY30
LCV	**0**	24,384	86,895
Total	**580,200**	**4,874,318**	**16,515,000**

Table 61: Outlook on EV Population in India

Vehicle type	FY19	FY24	FY30
E rickshaw	1,509,259	4,923,066	10,555,580
3W	100	719,196	4,646,598
2-W	227,250	8,720,413	59,318,340
Cars & UVs	5,039	366,224	5,295,937
Bus	610	17,783	158,222
LCV		50,901	425,870
Total	**1,742,258**	**14,797,583**	**80,400,546**

9.4 Assessment of Power Distribution Utilities

9.4.1 Country Macros and Policy Frameworks Guiding Utilities' Overall Performance

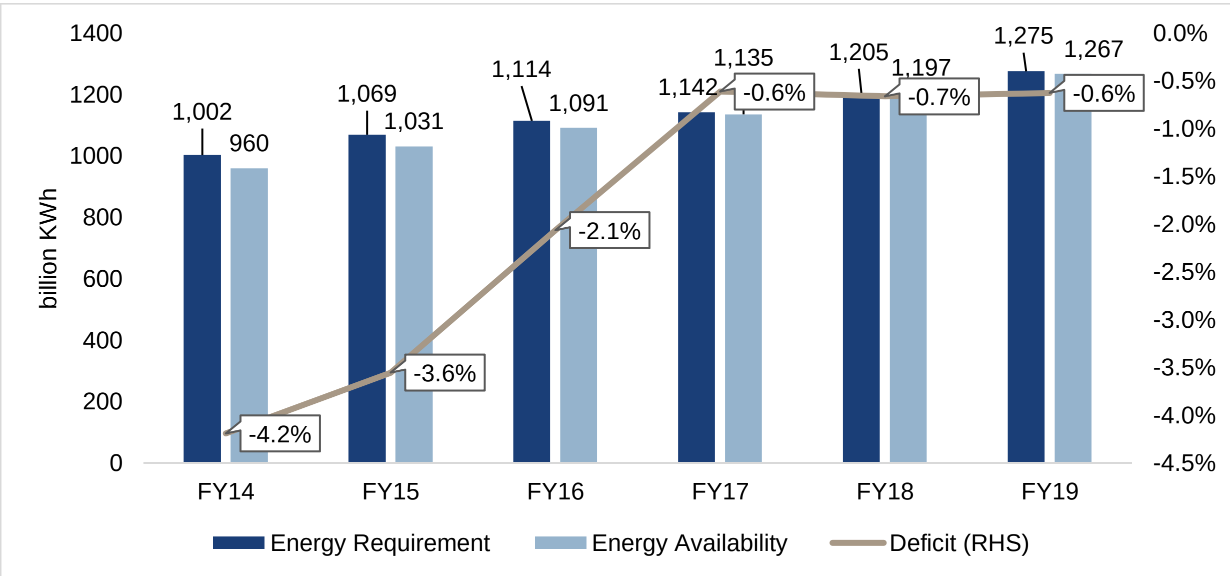
With population of over 1.3 billion and estimated GDP of USD 2.75 trillion in fiscal 2019, India is the third-largest economy, adjusted for purchasing-power parity (PPP). Also, India has favourable demographics with the largest working population – 66.2% of the total population – in the working age group of 15-64 years in 2017 (source: World Bank), and more than half the population below 25 years of age. In fact, India's working population is more than total population of countries such as Russia, Brazil and the US. Going forward, the working population, which logged 2% CAGR over 2007-2017, is expected to increase further, thereby driving consumption and growth.

The power sector in India is governed by the central and state regulatory agencies. The sector is highly regulated with various functions distributed between multiple implementing agencies. The three chief regulators for the sector are the Central Electricity Regulatory Commission, the Central Electricity Authority and the state electricity regulatory commissions.

The total installed generation capacity as of March 2019 was 356 GW, of which approximately 123 GW was added during the period from fiscal 2013. Coal-based installed power generation capacity has maintained its dominant position over the years and accounted for 56% as of March 2019. However, renewable energy installations have more than doubled to ~78 GW capacity, compared with 32 GW as on fiscal 2014, constituting ~22% of total installed generation capacity. In particular, this growth has been led by solar power, which grew at a break-neck speed to ~28 GW from ~3 GW over the same period.

Energy requirement clocked 4.2% CAGR over fiscals 2014-2019. However, the growth was volatile given the market conditions. Fiscals 2012 and 2013 saw healthy growth of 8.8% and 6.5%, respectively, on the back of robust growth in economic activity and improved power availability supported by capacity addition of around 20 GW in each year. However, the demand stagnated in fiscal 2014 on account of lower off-take due to weak financial health of electric utilities and slowing GDP growth. In fiscal 2015, the demand growth revived to 6.7% led by a pick-up in economic activity. Moreover, power off take in seven states improved in fiscals 2014 and 2015 post financial restructuring of electric utilities in those states. The growth tapered subsequently to 4.3% in fiscal year 2016 and 2.5% in fiscal 2017 owing to slowdown in manufacturing. In fiscal 2018 and 2019, the demand grew 5.5% and 5.8% respectively, mainly driven by increased connections through the rural electrification and Saubhagya schemes.

Figure 26: Aggregate Power Demand and Supply (in Billion kWh)

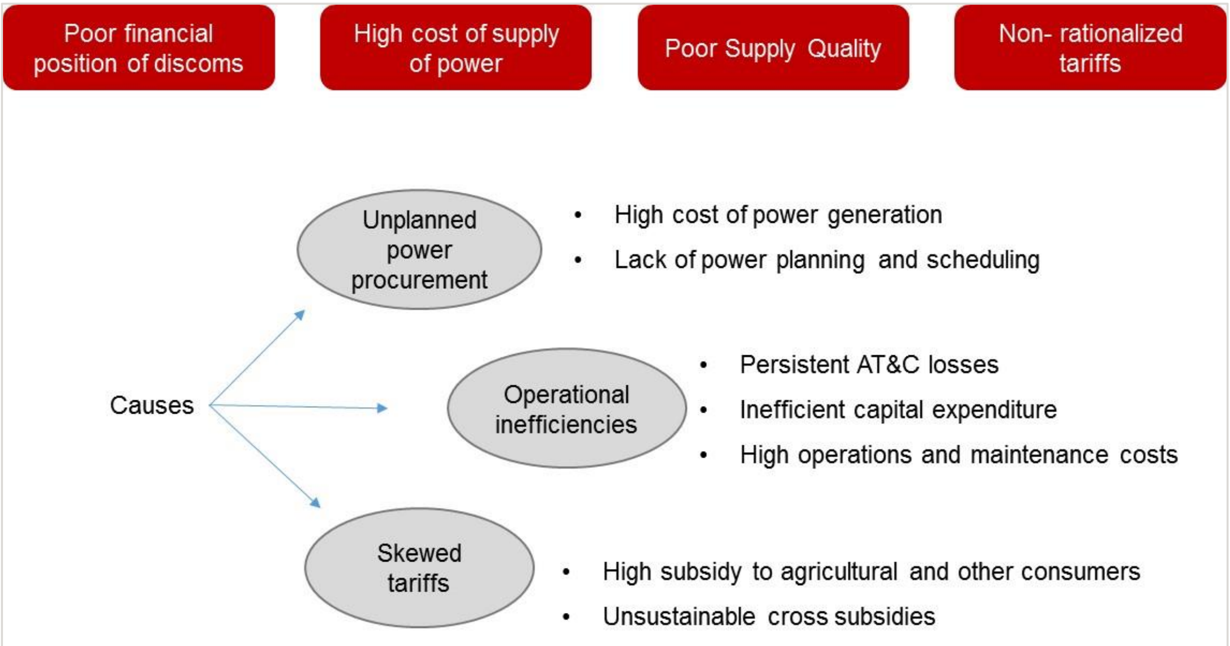


Energy demand increased at a CAGR of 4.2%, while power supply rose at a faster pace of 5.7% CAGR over fiscals 2013 and 2018 on the back of strong capacity additions and improvement in transmission infrastructure. Though energy deficit (difference between electricity requirement and supply) has been on a downward spiral, India remains a power deficit country in a growing demand scenario. Energy deficit declined to 0.7% in fiscal 2018 and to 0.6% in fiscal 2019 from a high of 4.2% in fiscal 2014.

Distribution is the last and critical leg in the supply of electricity - to reach end consumers such as residential, commercial, agricultural and industrial segments. With more than 200 million consumers and a connected load of ~400 GW, power distribution caters to one of the largest consumer bases in the world. The distribution business is largely dominated by state government-promoted electric utilities; private participation is marginal (5-7%). There are close to 73 distribution utilities – 13 electricity departments, 41 corporatised distribution companies, 17 private distribution companies, and two state electricity boards (SEBs).

However, the financial position of the distribution sector has significantly deteriorated over the past decade owing to irregular tariff hikes, high aggregate technical and commercial (AT&C) losses, and delays in subsidy payments by state governments. This has adversely impacted power offtake by electric utilities and led to a delay in payments to generation companies. The key problems faced by electric utilities are highlighted below:

Figure 27: Major Problems Faced by Electric Utilities in India



In order to improve the electric utilities' weak financial position, the Government of India (GoI) launched several centrally-sponsored schemes over the past 8-10 years.

1. **R-APDRP:** The MoP launched the Restructured Accelerated Power Development and Reforms Programme in 2008 with an aim to improve AT&C losses by enabling reliable and sustainable systems. It envisioned the establishment of supervisory control and a data acquisition system/ distribution management system. The total program size was INR 515,770 million through a combination of GoI grants and Power Finance Corporation (PFC)/ Rural Electrification Commission (REC) loans. The projects under the scheme are to be taken up in two parts. Part A will include the projects for establishment of baseline data and IT applications for energy accounting/auditing and IT-based consumer service centers. Part B will include regular distribution strengthening projects.

Progress: Under Part A, 1,402 projects at an estimated cost of INR 51,965 million have been approved for 29 states/union territories and Rs 1,578.67 crore disbursed. Under Part B, 1,084 projects at an estimated cost of INR 2,47,761.8 million have been approved for 20 states and INR 33,983.2 million disbursed as on December, 2018.

2. **UDAY:** Ujwal DISCOM Assurance Yojana was launched by the MoP for financial turnaround and revival of state electric utilities. It was aimed to help them become financially and operationally healthy. Under the scheme, the respective states are to take over three-fourths of the electric utilities' debt. The governments will issue UDAY bonds to banks and financial institutions to raise money for paying the banks. The remaining 25% of the loans will be converted into low interest-rate bonds or be funded by money raised through electric utility bonds backed by state guarantee. For the bailouts to materialise, there are a few caveats such as reduction of AT&C losses to 15% by fiscal 2019, installing smart metering, revising power tariffs in tandem with power purchase and other operations and maintenance (O&M) costs incurred.

   Progress: With INR 2.3 trillion worth of bonds being issued (86.3% of target) as of March 2019, debt and interest burden on electric utilities has been reduced, resulting in higher liquidity. Aggregate electric utility debt fell from INR 2.7 trillion in September 2015 to INR 1.9 trillion in fiscal 2016 and INR 1.5 trillion in fiscal 2017. However, the declining debt trend is expected to reverse from fiscal 2019 onwards as capital expenditure to improve distribution infrastructure and operational losses is largely funded through external debt by electric utilities. ACS-ARR gap for UDAY states reduced to INR 0.17 per kWh in fiscal 2018 from INR 0.41 per kWh in fiscal 2017, but expanded to INR 0.22 per kWh at the end of fiscal 2019 (as per provisional numbers reported on the UDAY portal), indicating reversal of some of the gains achieved through reduction in power purchase costs, interest burden and AT&C loss reduction over the past three years.

9.4.2 Benchmarking of Utilities

Objective

The broad scope of this project is to develop an action plan for distribution utilities on the introduction of EV public charging infrastructure in three geographies: India, Pakistan and Bhutan. As a first step, distribution utilities in India and Pakistan should be benchmarked on financial, operational and other key parameters (preparation of regulatory framework, assessing utilities with the existing charging infrastructure, etc.). The utilities will be graded on the parameters and one utility from each geography will be shortlisted based on a final composite score. With Bhutan having only one distribution utility, the same set of parameters will be a starting point for developing an elaborative action plan for introduction of charging infrastructure in the country.

Methodology

In order to shortlist an electric utility in India, it is imperative that different utilities are benchmarked and ranked. There are 73 electric utilities in India. Therefore, in order to compare the utilities on an aggregate basis, a comprehensive set of parameters, grouped in buckets, have been selected. Each parameter has been assessed for significance, materiality and degree of explanatory power with respect to the final desirable outcome. A few parameters were dropped owing to data paucity across the utilities or being non-comparable due to unavailability of data across the same timescale. The final set of parameters is given below along with the rationale for selection:

Table 62: Parameters adopted for Benchmarking of Utilities

Bucket	Parameter	Rationale for Selection
Operational Metrics	AT&C losses	Provides a realistic picture of loss situation for the utility by taking into account energy loss (Technical loss + Theft + inefficiency in billing) & commercial loss (Default in payment + inefficiency in collection)
	Distribution losses	Measure of power lost during transit as a percentage of power injected into the distribution grid
	Collection efficiency	Indicator of proportion of amount that has been collected from consumers with respect to amount billed to them
	Billing efficiency	Indicator of proportion of energy that has been billed (includes both metered and unmetered sales) to consumers with respect to energy supplied to an area
Financial Metrics	Total power sales	Assessment of revenue strength, number of consumers and geographical coverage for the utility
	ARR/sales	Indicator of realized revenue for each unit of power sold to consumer. Measure of inefficiencies in realization
	O&M/sales	Operation and maintenance cost as a percentage of utility total revenue. Too low O&M cost may result in a need in very high investment and O&M cost in the future. Too high O&M cost indicate generic problems for the utility
	Gap (as % of ARR)	Percentage of gap with respect to realizable revenue
	ACS-ARR gap	Gap between average cost of supply and average realizable revenue. Indicator of tariff irregularities and/or realizations
	APPC per unit of energy sales	Measure of cost incurred by the utility to procure power from generating sources
	Age of creditors	Measure of financial performance and liquidity position
Other Key Parameters	Surplus (+)/ deficit (-) of the state	Measure of power supply position in the state with respect to demand.

Bucket	Parameter	Rationale for Selection
	Peak surplus (+)/ deficit (-) of the state	Indicator of the state's capability to meet peak demand scenarios through short term power arrangements
	Upcoming industrial and commercial clusters	Indicator of rise in financial situation of the state/ area, growth in per capita income and propensity to buy high valued items (like EVs)
	Policy/ implementation framework rolled out by the utility	Federal/ state support for enablement of EV ecosystem in the area

The benchmarking study covers 17 parameters across three buckets to establish the position of each electric utility in the country among its peers. The intended outcome of the study is to determine the current position of the utilities (as measured by the final and composite rank). Each utility has been rated as 1/2/3/4 on each parameter based on the pre-decided rating buckets. Finally, a composite rank is assigned to the utilities on the basis of the cumulative score (across three major buckets). The electric utility which fares the best (rank 1) will be selected for detailed assessment in the respective geography.

The benchmarking study consists of statistical and non-statistical parameters to ensure finality. In the context of introspection and authenticity, the study has utilised data only from authentic sources: government reports or disclosures/tariff orders by electric utilities available in the public domain.

Readiness of Electric Utilities to Set Up EV Charging Stations

In India, 37 major electric utilities have been assessed, benchmarked and ranked. The rest were left out as they were inconsequential and did not alter the results in the study. Out of the 37 utilities, some performed significantly well across categories and buckets, while a few lagged consistently. The exercise has found several electric utilities at the helm of the study results with a little differentiation. The two non-quantitative parameters - upcoming industrial & commercial clusters, and policy/ implementation framework rolled out by the utility - were given more weightage to eliminate the clustering effect at the top. This makes logical sense as the two factors are typically proxies of demand and supply drivers of EV charging infrastructure in a region. Higher the industrial and commercial development, higher the affluence in the region, leading to a greater propensity of residents to buy an EV. With EVs still expensive and considered exclusive in the country, wealth and improved disposable income are expected to govern initial sales. The second parameter (policy/ implementation framework rolled out by the utility) has been selected and each utility has been ranked taking into account policy formulations made by the state and/or utility pertaining to EVs. Karnataka, Maharashtra, Telangana, Andhra Pradesh, and Gujarat have already formulated EV polices, while a few other states such as Uttar Pradesh are on the drafting table. Many electric utilities in Telangana, Andhra Pradesh, Karnataka, Madhya Pradesh, Chhattisgarh, and Delhi have declared tariff structures for EV charging stations. Such developments were taken into account for ranking.

9.4.3 Shortlisted Utility

The following electric utilities have been identified from India (based on the top three final rankings):

Name of Electric Utility	Area of Operation
Tata Power	Mumbai
Maharashtra State Electricity Distribution Company Ltd (MSEDCL)	Maharashtra (except Mumbai region)
BSES Yamuna Private Ltd	South-East, North-East & Central

Based on the interest evinced by the shortlisted utilities and the intention to mutually work on the project, BSES Yamuna Private Ltd (BYPL) was finalised for further research.

9.5 Gap Analysis for the Shortlisted Utility

BSES Yamuna Private Limited (BYPL) is a private electric utility (a joint venture between Reliance Infrastructure Limited and Govt. of NCT of Delhi with a 51%: 49% shareholding) serving power to the Eastern and Central parts of Delhi. It has a licensee area of ~200 square kilometres and caters to ~1.73 million consumers.

While devising a detailed business plan for BYPL to introduce charging infrastructure, the electric utility was benchmarked with globally recognized utilities which have undertaken significant EV (or e-mobility) programs. This helped assess major gaps in BYPL’s standings with respect to driving e-mobility, especially EV charging stations in its licensee area. The major gaps for BYPL in that regards are as follows:

Table 63: Gap Analysis for BYPL for Implementing Charging Infrastructure

1. Pricing Programs	
Pricing Programs for EV owners (lease model/ grant model)	No
Rebate offered to the consumers for purchase of EVs	No
Subsidy on EV chargers set up in its licensee area	No
Separate power rates for EV charging	Yes
Off peak charging (ToU) rates for EVs	No
2. Implementation Measures	
Promoting awareness for e-mobility through targeted advertising	No
Conducting consumer awareness surveys and facilitating sale of electric vehicles	No
Facilitating set-up of EV charging stations by connecting with interested players	Yes

Installing behind-the-meter electric equipment for EV chargers and undertaking remote monitoring	Yes
Undertaking grid augmentation measures to support EV charging stations	Yes
Internal business plans to implement e-mobility	No
3. Organizational Capacity Building	
Organizational planning to implement e-mobility	Yes
Skill development and competency building towards e-mobility	Yes
Leadership vision to enable E-Mobility, especially EV charging stations	No clear vision

9.6 Planning for the Transition

9.6.1 Charging Standards and Charger Type

In order to create an ecosystem of EV charging stations, it is imperative to have a standard for all EV supply equipment (EVSE), as required. The purpose of standards is (a) to act as a guiding principle for manufacturers to meet necessary specifications, (b) set a reference for testing agencies such as ARAI and ICAT to carry out required tests, and (c) facilitate talking (communicating) between different charging systems that may co-exist in a country.

The Bureau of Indian Standards (BIS) had set up the ETD 51 Committee for forrmulating the standards pertaining to EV charging (sockets, plugs, and vehicle couplers). It has already finalised and released the IS:17017 standards, which pertain to charging systems in the country.

Table 64: Standards Pertaining to EVCS

Standards	Description
IS:17017 series of standards	Based on IEC 61851; IEC 62196 and ISO 15118 series of standards
IS:17017-1	General requirements and definitions of EVSE (adapted from IEC 61851-1)
IS:17017-21	EV requirements for connection to AC/DC supply (adapted from IEC 61851-21)
IS:17017-22	AC EVSE (adapted from IEC 61851-22)
IS:17017-23	DC EVSE (adapted from IEC 61851-23)
IS:17017-24	Digital communication protocol between DC EVSE (fast charging systems) and EV
IS/ISO:15118	Digital communication protocol between CCS-based EVSE and EV

Source: BIS, DHI

The IS-17017 recommends CHAdeMO and CCS charging protocol and has adopted the same for rolling out DC charging systems. In 2017, the Department of Heavy Industries (DHI) issued Bharat Charger specifications for AC [Bharat Chargers AC-001 (15A, 3.3kW, IEC 60309 connector)] as well as DC chargers [Bharat Chargers DC-001 (200A, 15kW, GB/T 20234 connector)] based on the Chinese standard - GB/T. However, Bharat Chargers are for vehicle architecture lower than 100V.

Initially, two-wheelers (personal or ride sharing), autorickshaws and cab aggregators (Ola and Uber) are expected to go electric. While personal vehicles can make do with AC slow chargers for the timebeing, the same is not feasible for commercial vehicles (CVs).

The most viable solution for CVs would be battery swapping, but it is subject to battery standardisation and creation of a well-connected ecosystem across the country. There are no national or international standards for battery swapping because different vehicles use batteries of a different make, configuration and technical parameters, which require different charging modes (voltage and current levels). In order to bring out a battery swapping regulation in the country, vehicle manufacturers and battery suppliers will need to build a cohort and install standardised batteries. Regulators can go to work once the ecosystem is in place.

In late 2018, the government had asked public charging stations to install all three fast charging platforms, CCS CHAdeMO and type 2 AC, as well as two slow/moderate chargers - Bharat DC and Bharat AC. The charging standards as highlighted in the MoP's notification titled “Charging infrastructure for Electric Vehicles – Guidelines and Standards” dated December 2018, are as follows:

Table 65: Charger Types and Rated Voltages for EV Charging (as per the MoP’s Notification)

Charger Type	Charger Connectors	Rated Voltage (V)	No. of Charging Points/ No of Connector Guns (CG)
Fast	CCS (min 50 kW)	200-1000	1/1 CG
	CHAdeMO (min 50 kW)	200-1000	1/1 CG
	Type 2 AC (min 22 kW)	380-480	1/1 CG
Slow/ Moderate	Bharat DC-001 (15 kW)	72-200	1/1 CG
	Bharat AC-001 (10 kW)	230	3/3 CG of 3.3 kW each

Source: Ministry of Power, India

Deployement of all charger types will lead to escalation in costs as plugs and communication protocols, which adhere to prescribed standards, have to be deployed. Residential and captive charging infrastructure for internal use of a company’s own/ leased fleet is not required to install all types of chargers. Lack of clarity on charging standards had earlier forced Energy Efficiency Services Ltd (EESL) to annul the tender for buying 10,000 EVs in 2018. The tender had a 20% quota for luxury sedans, which would have required incorporation of fixed charging standards in the country.

In July 2019, the DHI had issued an EoI for setting up 1,000 EV charging stations in cities. As per the notification, the charging stations must have at least six chargers – four fast and two slow. The charging technologies must include CHAdeMO, CCS, Bharat Standard and Type 2 AC. The rated voltages of these charger types as recommended by the DHI's EoI are given in the table below:

Table 66: Charger Types and Rated Voltages for EV Charging

a. Should contain minimum five chargers of any one or any combination of charger type stated			
Charger Type	**Charger Connectors**	**Rated Voltage (V)**	**No. of Charging Points/ No of Connector Guns (CG)**
Fast	CCS (Min 50 kW)	200-750 or higher	1/1 CG
	CHAdeMO (min 50 kW)	200-500 or higher	1/1 CG
	Type 2 AC (min 22 kW)	380-415	1/1 CG
Slow	Bharat DC 001 (15 kW	48 or higher	1/1 CG
	Bharat AC 001 (10 kW)	230	1/1 CG
b. *Should contain at least one charger from the charger given below having appropriate charging guns to charge all types of vehicles, i.e. the charger should have two guns - one each for CCS and CHAdeMO*			
Fast	CCS (Min 50 kW	200-750 or higher	1/2 CG
	CHAdeMO (min 50 kW)	200-500 or higher	1/2 CG

Source: DHI

Policy Clarifications Required

- Medium and high voltage EV charging standards are under consideration. AC-002 and DC-002 are still being worked on
- Interoperability between AC-001, AC-002, DC-001 and DC-002. Mechanical connectors, communication systems (physical and software), clustering and mounting platforms with respect to the protocols are yet to be decided
- Policy regarding communication link for home charging systems for EVs is still to be decided. The electric utilities may need the same to carry out better load management
- At present, EV charging occurs over a standard 15A socket. Potential extension for AC-001 standard to account for larger vehicles is awaited
- Standards pertaining to battery swapping are awaited

Expected Traction of Chargers

In India, we expect the initial traction to be towards installation of slow chargers. This will lead to a concept of EV bays, where the EV will be parked at a particular slot beside a road/ outlet/inside a garage and charged at the station. The Ministry of Housing and Urban Development has mandated that 20% of the parking (vehicle holding capacity) in residential and commercial complexes has to be alloted for EV charging and eateries have to reserve space for EV kiosks. This will be a boon for users who park their vehicles regularly (either at home or at office). With electric two-wheelers in the Indian market promising a range of 50-70 km and four-wheelers having a range of 80-100 km on a single charge, range anxiety is unlikely for most regular office commuters. This will enable usage of EVs by making do with slow chargers. Small vehicles (two- and three-wheelers) can charge through three-pin type 1 chargers whereas larger vehicles (four-wheelers) can charge through seven-pin type 2 or type 3 chargers. The EV charging stations will have to be equipped with different sockets that are compatible with the chargers.

However, slow charging will not be compatible with vehicles deployed for commercial use. Although battery swapping is an efficient solution, as per industry sources, it requires an expensive and intensive infrastructure which is not expected to materialise in the country soon. Also, it requires standardisation of batteries (size/ power output/ charging methodology).

From an Indian perspective, NMC batteries are best-positioned taking into account the usage pattern. Hence, further uptake of the battery in EVs is projected.

As per guidelines from the Ministry of Power dated December 2018, public charging stations (PCS) are required to have three fast charger connectors (CCS, CHAdeMO, and Type-2 AC) and two slow charger connectors (Bharat DC 001 and Bharat AC 001). However, upfront costs pertaining to installation of five chargers at a PCS is prohibitive and, hence, may not be feasible in the short-to-medium term. Therefore, it is to be seen how the policy takes shape to assuage the high CAPEX cost. In October 2019, the government had brought out an amendment to the charging station guidelines, stating that PCS owners have the freedom to install the chargers (type as well as number) as per the market requirement.

Fast charging standards, which are being worked out for India (AC 002 and DC 002), are still awaiting standardisation. Internationally, PCS do not deploy all connectors, and no two connectors are interoperable. China has built scale by defining and adopting its own charging standards**.** The opportunity for India is to do the same by leveraging existing technologies and taking into consideration India-specific needs. Sound policies, clear standards, and private participation will pave the way for faster adoption of EV chargers.

DC charging (through CHAdeMO or CCS) entails several issues for a nascent EV market like India:

- **High CAPEX**: DC fast chargers are currently expensive, involving a CAPEX of ~INR 2.5 million. Also, appropriate devices that allow fast charging are not readily available. These are disincentives for companies looking to install fast chargers. Additionally, EVs currently available in the market have small batteries, and, hence, do not need fast charging to the same extent as larger battery-fitted vehicles do

- **Unavailability of vehicles**: Globally, EV manufacturers have pushed for larger batteries to improve usability and range. The first generation Nissan Leaf had a battery size of 24 kWh, which has undergone several upgrades to reach 62 kWh in 2019. The Tesla Model X 100D has pushed the limits, packing in 100 kWh. In comparison, the two Indian EV cars, Mahindra e2o and Tata Tigor EV, use 16 kWh battery packs. Even the new Tigor, launched in October 2019 has a battery capacity of 21.5 kWh. Only one car, Hyundai Kona (battery capacity: 39.2 kWh) might require fast charging owing to its large battery size. It will take at least some more years for Indian manufacturers to introduce batteries of ~50 kWh, and another 2-3 years to make these cost-competitive as prices of battery packs reduce.

Although standardisation of chargers and protocols are mostly in place, usability remains a concern. This is because the standards, borrowed from developed EV markets, are difficult to replicate in the Indian context, at least for another 5-6 years. The EVs expected to come up (2W/3W/4W) in the near future will deploy small battery packs (<50 kWh) for which slow charging standards will be more suitable. The Bharat AC and DC standards will cater to charging requirements for the time-being. Charging will predominantly be through home-installed chargers and EV parking bays (installed in garages, housing societies, commercial spaces) deploying slow charging systems.

For households, the supply is typically limited to ~15 kW. An average (single phase) house can install an appropriate EVSE, subtracting household usage from other connected load. In the US, a residence has options of installing a 3.6 kW or 7 kW EVSE. For EV parking bays, slow AC chargers can be used to top up the vehicle while it is parked.

As the Indian market gains traction with new EV availability, better consumer electronics and bigger Li-ion battery packs, the fast charging infrastructure will develop.

Table 67: Potential Roadmap for EV Charger Adoption in the Country

Initial phase	Slow chargers	**EV parking bays** equipped with charging facilities; vehicles will be charged at home / office/ parking lots
Intermediate phase	Fast chargers	**EV charging stations** on major highways, thoroughfares in tier 1 cities
Maturity phase	Fast chargers with CMS	**Connected EV charging stations** enabling smart charging, secure transactions, V2G

9.6.2 Battery Swapping

India is a very nascent market for EVs. Going forward, the advent of EVs in the country is expected to be in the 2W and 3W segments, owing to favourable TCO economics, lower COA, and higher government subsidies. With the Indian automobile sector comprising majorly of 2Ws and 3Ws (~80% and ~3% of the overall vehicle population, respectively), the ramifications of these vehicle categories going electric is significant.

While 2Ws are mostly used for personal usage, commercial usage of 2Ws in the form of shared mobility, last mile delivery of goods (food, shipments, etc) is gaining prevalence. With already 0.2 million e-2W and 1.5 million e-3W (including e-rickshaws) on Indian roads, the business case of electrification is strong. Niti Aayog in its policy document on EVs has also highlighted that India needs to focus initially, at least for the first few years, on 2Ws and 3Ws.

Commercial 2Ws and 3Ws will require quick charging systems and will not want to wait for 3-5 hours for charging vehicle’s batteries as it will hamper business. This is why Ola Mobiliy’s pilot EV project failed to gain traction in the Indian city of Nagpur. Several taxi owners who had leased the EVs from Ola at Rs 1,000 per day were finding it difficult to meet revenue targets owing to less battery mileage and high charging times. Building an EV with bigger battery is also counter intuitive as prohibitive cost and lack of fast charging will not encourage sales. Battery swapping can be the sweet spot to achieve scale where public charging infrastructure is unviable.

With government support and industry trends favouring e-2Ws and e-3Ws, battery swapping stations to cater to the categories can help accelerate commercial usage.

Ecosystem of Battery Swapping in the Country

Although there is no mention of swapping stations in the policy documents so far, certain companies in India are exploring the opportunity of setting up BSS in the country. Some forays that have been done by companies in India are:

- Sun Mobility is working with Ashok Leyland on its pure electric buses plying in Ahmedabad, and with Delhi-based e-rickshaw startup, SmartE. In Ahmedabad, 18 buses are presently equipped with swappable batteries, with the swapping infrastructure handled by Sun Mobility. In Delhi, it provides swap solutions to SmartE’s fleet of 45 electric 3Ws, which is expected to be ramped up to 500 e-rickshaws soon
- Sun Mobility is also working with Pune-based Piaggio Vehicles to co-develop a business model around electric 3Ws. Piaggio intends to separate the battery of the 3W to reduce upfront cost. Sun Mobility has been mandated to supply batteries to Piaggio along with swapping solutions
- Exicom Power Solutions has an order book to set up ~120 battery swapping stations in Delhi NCR

over the next two years. Majority of these stations will cater to the commercial e-2Ws and e-3Ws

- 22Kymco, a collaboration between India-based 22 Motors and South Korea-based Kymco, recently launched the iFlow electric scooter. It plans to set up ~240 swap stations (and fast charging units) in six cities - Ahmedabad, Bengaluru, Delhi, Hyderabad, Kolkata, and Pune - by March 2020
- Ola Electric has been working towards developing an electric mobility ecosystem in the country, which includes charging stations, swapping solutions and other products. The company intends to focus on 2Ws and 3Ws in the short-to-medium term
- Panasonic India has been conducting pilot programmes on battery swaps in the NCR

9.6.3 Grid Augmentation

Although a shift from ICE vehicles to EVs is crucial to minimise greenhouse gas emissions of the transport sector and reduce India's dependence on fossil fuels (petrol and diesel), one needs to bear in mind the challenges that will accompany the transition. One of the major challenges is the imposition of additional burden on the power grid, as increasing number of charging stations and drawl of power will degrade the operating parameters of the distribution network, making it unreliable and inefficient.

Power Requirement for EV Charging Stations

EV penetration is minuscule in the country, at <0.5%. To build a comprehensive framework for a utility to augment the EV charging infrastructure in the country, taking into account the expected growth in EV sales, the ramifications needs to be looked into.

Low voltage architecture vehicles like e-2Ws and e-3Ws utilise AC charging, which is typically slow. For high powered fast charging, current drawl is higher.

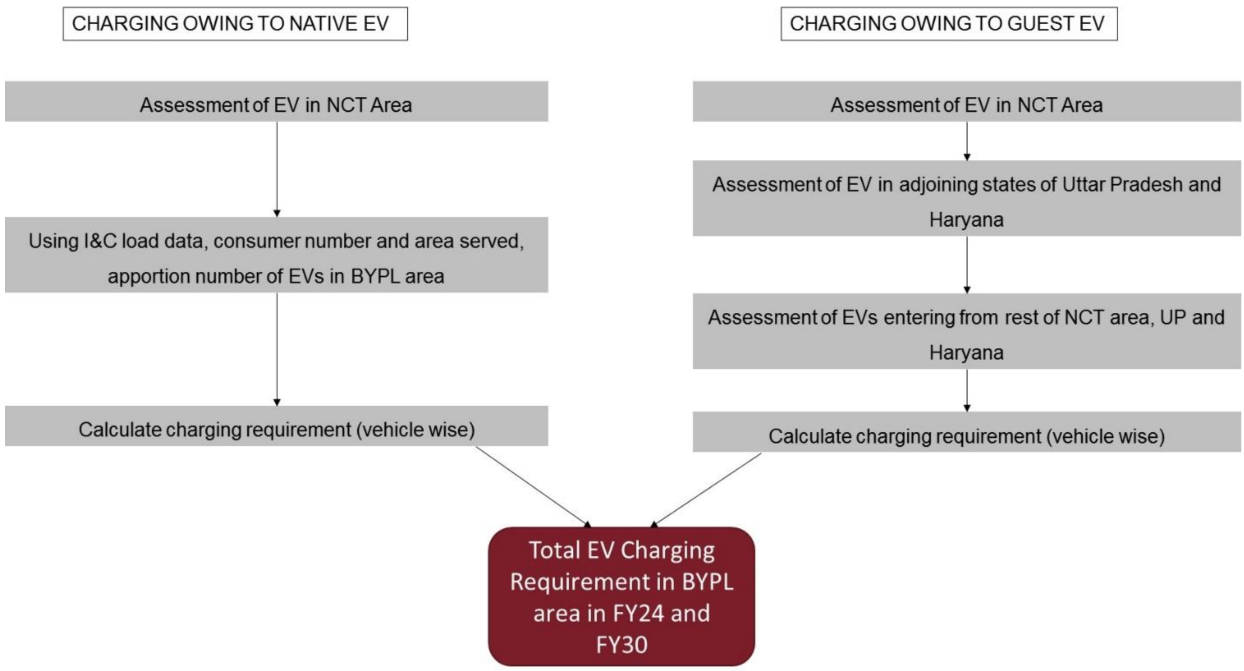
Slow charging is majorly used for personal charging systems (home/ office) while fast (DC) charging can be used at public charging/ dedicated fleet charging points. The power rating for DC charging is significantly higher, as it allows the charger to pump more power into the battery in a short time.

Table 68: Charging Methods and Power Ratings for Different Power Ratings

Power Rating (as per SAE)	AC Charging	DC Charging
Level 1	<2 kW (single phase AC)	<36 kW (80 A)
Level 2	<22 kW (single phase AC)	<90 kW (200 A)
Level 3	<43 kW (three phase AC)	<240 kW (400 A)

Impact on Grid for BYPL

In order to understand the impact of EV charging on the grid, a detailed analysis of the prospective number of EVs which are expected to charge in the BYPL area was performed. Judgment calls on EV growth (vehicle wise) till FY30 was taken not only for the National Capital Territory (NCT) but also for neighboring cities of Ghaziabad and Noida (due to close proximity with the BYPL area). Cumulative charging requirement owing to native EVs (EVs owned by residents in the BYPL area) as well as guest EVs (travelling from other parts of Delhi and adjoining cities of Ghaziabad and Noida) was calculated. The methodology is as given below:



It was found out that additional load data owing to EV charging will be nominal as shown below and no additional grid augmentation is expected to be necessitated till FY30.

Table 69: Additional Load Emanating from EV Charging in BYPL Licensee Area

In MUs	**FY24**	**FY30**
Native Charging	136	571
Guest Charging	107	144
Total	243	715

By using ToD and ToU differential tariffs, peak demand from EVs can be met to an extent. In other cases, additional DTs may be installed where aggregation of EVs are found to be more.

Way Forward

With changes in network parameters owing to rise in usage of EV charging stations, grid efficiency could reduce. Major influencing factors include EV types, travelling distances, vehicle efficiency, battery sizes, charging time slots, type of charging [slow/fast], and user charging patterns. In light of proliferation of EV charging stations, demand variability is expected to increase. The issue could get aggravated because of increasing variable generation (VG) sources getting connected on the supply side. Hence, demand response management will become more challenging with EV adoption as charging becomes commoditised and commonplace. The electric utilities need to play an important role in managing load imbalances.

The prospective solutions and way-ahead strategies are:

Remediation Strategies

Similar to rooftop solar photovoltaic (PV) projects, EV charging stations have a problem of peak energy requirements due to uncertain charging and discharging patterns of consumers. This uncertainty makes it difficult to accurately assess impact on the local distribution network. The transmission and distribution network will require adequate augmentation with rising penetration in EV chargers. Hence, the electric utilities are required to have special planning and intervention to address challenges emanating from EV charger adoption:

- **Optimal placement of charging stations** – An electric utility has the onus to ensure seamless and reliable power supply to all charging stations set up under its distribution area. For this, the utility must undertake a techno-commercial feasibility study before providing electricity to the station. This should include detailed studies on the impact on the grid, peak load, and transformer loading owing to additional EV load. The utility needs to take into consideration the ideal number of fast and slow charging stations that can be catered to by the network without compromising on reliability. The committee on Technical Aspects of Charging Infrastructure for Electric Vehicles, led by the CEA, has stated that in view of effective grid and network management, permission from the utility before setting up a PCS is mandatory. Additionally, the CEA has said that the location for the PCS will be decided by the electric utility, state road transport department, and urban development department of the state

- **Distribution network planning along with adoption of distributed generation:** Adoption of EVs generally have a clustering effect, with significant uptake in upscale neighbourhoods of a metropolis. This makes EV integration more challenging. Neighbourhood clustering puts significant pressure on the local grid network. Hence, infrastructure upgradation requires strategic planning. As per a UK study, ~32% of low voltage feeders will require reinforcement by 2050 to cope with the EV clustering effect. This amounts to GBP 2.2 billion of investments by 2050, which may further be exacerbated if consumers opt for high capacity DC chargers.

- **Network reinforcement** investments can be reduced via distributed generation. This will reduce distribution losses, improve reliability issues, and encourage bidirectional flow of power in the grid. Instead of the conventional method of augmenting upstream electricity systems (additional power plants), distributed generation will lead to network reinforcements at low-voltage levels, thereby averting high power losses at the distribution level

- **Reconfiguration of distribution networks:** Typically, distribution transformers between 10-50 kVA will serve majority of the EV charging stations. The clustering phenomenon will cause damage/ outage from overloading of the DTs, thereby degrading the power quality in other connected residential/ commercial feeders. Also, intermittent voltage fluctuations will lead to rampant heating up and cooling down of transformers, impacting their life and reliability. This will, in turn, affect SAIFI and SAIDI of the network. Therefore, in order to manage the EV load on a network, the electric utility must forecast EV peak load and build central monitoring systems for DTs. Feeders that have tendencies of high transformer loadings need to be upgraded. As per the CEA, a CMS will be set up by the utility to enable maximum charging rate, which will be controlled based on availability of power in the grid
- **Time of use charging:** Network loads can be managed though special EV tariffs with lower prices during off-peak times. This can help shift the EV load through peak shaving (during times of high load) and valley filling (during times of low to moderate load). ToU can help electric utilities avert buying costly short-term power from the open market to cater to peak demand. Instead, through gradual valley filling, demand load can be met via power generation from base load stations. However, this solution may be tenable at low EV adoption times and not at high penetration levels, as seen in the case of California, USA. At high EV levels, ToU charging in California had led to crowding behaviour, leading to sharp load ramps, thereby defeating the purpose of demand-side load management
- **Managed charging:** Although ToU intends to assuage / dissuade consumers to charge at a particular time slot, aggregation of charging at the particular time slot will again lead to overloading of DTs and sudden valley filling. Managed charging is to tackle the problem of crowding through gradual valley filling. Also known as intelligent or smart charging, managed charging entails a combination of infrastructure and communication signals. Messages will be sent directly to a vehicle via the charger, thereby influencing the decision of charge timing. Through managed charging, the end-user will have information of present EV charging tariffs at a current location as well as in neighbouring areas. The variation in tariffs will be governed by current DT loading in the respective areas, and the user will have the option to choose the right time and location of charging. Through this mechanism, governed by a real time CMS, users will be incentivised to charge in areas that are under-loaded.
- **The degree of incentivisation will be decided based on an intelligent algorithm** and not on a pre-determined ToD rate. This will make customer charging behaviour elastic, reducing the need of

polluting thermal peaking plants. A study titled “Digitization and Energy”, published by the IEA, quantified the benefits of managed charging at a global level. The study found that in a medium growth EV scenario, 150 million EVs will be on the road by 2040, and 140 GW will be required to cater to the charging requirements if standard EV charging is deployed. However, if managed charging is implemented, the capacity requirement will be cut by half (65 GW), thereby saving $280 billion for transmission and distribution investments and $100 billion for power generation capacity commissioning

- **Vehicle to grid**: It is one of the most advanced methods of smart charging, by which energy stored in EV batteries is discharged back to the grid, thereby making EVs virtual power plants. This two-way charging can help EV owners to charge their vehicles when power is the cheapest and discharge during peak load demand. This takes the value proposition of demand response to greater heights, improving asset utilisation, and increasing reliability and resiliency of network parameters, such as voltage control, frequency regulation, etc. A Nissan-led V2G trial in Denmark in 2017 found that EV owners could earn up to 1,300 euros a year by supporting grid balancing. Another trial run, sponsored by the United States Department of Defense, undertaken to assess the economic benefits of V2G from a network of 42 EVs, found it to be between $1,800-2,500 annually to EV owners by providing capacity-based services to the system operator, California Independent System Operator. Although V2G is a far-fetched concept for India, the utility must work towards implementing managed charging (supply-side incentive) and ensure that the local distribution network does not get overloaded, by setting up a CMS to manage DT loading positions on real-time basis. Supply to charging stations must be ensured, and captive generation as well as open access at EV stations must be expedited.

9.6.4 Charging Locations

Table 70: Typical Locations that can be Considered for a PCS in India

Type of Area	Prospective Locations for Charging Stations
Urban Areas	Parking lots of residential complexes/ housing societies
	Premises of public offices/ government hospitals/ government educational institutions
	Near commercial establishments (coffee shops, restaurants, movie theatres, shopping malls, eateries, market complexes)
	Technology parks
	Municipal parking lots
	Petrol pumps
	Dedicated parking spots on roads

Highways	Rest areas	
	Wayside amenities (coffee shops, restaurants, eateries)	
	Petrol pumps	

In the initial stage, India can consider setting up PCSs at/ near commercial centres and dedicated parking spots in upscale areas. For this, utilisation levels need to be assessed before and strategies developed. Although the government has proposed setting up a charging station every 3 km in cities and 25 km on highways, moving towards the target one step at a time is important. Building a lot of charging stations anticipating EV demand to grow in future, seems farfetched in the early years, when EV population is low, charging stations are expected to be underutilised. As EV sales grow and utilisation of existing stations improves, newer stations may be planned at strategic locations. This will keep a balance between the "chicken" and the "egg". However, as EV population rises significantly, there may not be a direct relationship between incremental EV sales and usage per EV charging station. As per a 2018 study conducted by the International Council on Clean Transportation, in several developed EV cities like San Jose, Seattle, and Amsterdam, usage per PCS has reduced despite rise in EV population. This introduces the idea of coverage versus capacity. Capacity planning takes into consideration more divergent factors like charging behaviour, driving pattern, and proximity of PCSs to end users, to determine ideal charging locations. Capacity planning is required when EV penetration is high and coverage of charging station is no longer the only factor determining station location.

Fast charging is mostly required along highways and expressways where EV users can quickly top up their vehicles before continuing their journey. The propensity to pay higher for charging is also greater on highways due to the psychological fear of getting stuck or running out of battery. This can, to some extent, assuage project viability risks even if utilisation levels are not optimum. The expectation that price premium charged to users will be able to cover the higher CAPEX (due to fast charging) and incremental OPEX may encourage prospective PCS owners to set up more stations.

In cities, however, pricing pressures are expected to dissuade rampant PCS expansion. The type of chargers (slow/fast) to be used will be dictated by government rules in case subsidy support is sought. Otherwise, the type and make of chargers to be used will be based on the end-use demand and policy intervention. Typically, in cities, slow chargers may be used where cars can be parked for several hours.

In India, like other developed markets, majority of the EV charging will happen at home, followed by charging at workplace. However, PCSs will be required to top up for trips beyond home or workplace. Further, plug-in hybrids may use PCSs to reduce running costs by powering the vehicle through its batteries. As per the US Department of Energy's Clean Cities Program, the presence and visibility of PCSs in a country will enhance the confidence among EV consumers as well as encourage prospective buyers to adopt EVs.

For a country like India, where consumers are not receptive to technology, development of trunk infrastructure can lead to faster adoption of EVs.

Case for BYPL

BYPL serves 14 divisions in Central, Eastern and North-Eastern Delhi. In order to ascertain locations for prospective PCS installations, each location was assessed based on four major parameters: (a) Economic Profile (b) Connectivity (c) Availability of public spaces (d) Proximity to commercial hotspots. The following six divisions out of 14 divisions have been found to be suitable for setting up of PCS.

The division-wise details for the six shortlisted divisions are given below:

Table 71: Division-wise Profiling in BYPL Area

Divisions	Circle	Type of Area	Economic Profile	Connectivity
Mayur Vihar	North East	Residential	• Developed residential area comprising a mix of CGHS and DDA flats with excellent social infrastructure • Proximity to both the central business districts of Connaught Place, New Delhi - Barakhamba Road to the east and Sector 15-18 of Noida to the south • Hosts several schools, colleges, hospitals, clinics, markets, sports complexes, gyms, banks and public parks • Key infrastructure includes international schools, super speciality hospitals, malls, etc	Sound connectivity through Noida link road, DND flyway, Delhi-Meerut expressway and Blue and Pink Metro lines
Shankar Road	North East	Residential	• The place is close to CP (~5 km), karol bagh (~2.5 km) and Patel Nagar (~3 km) • This makes the place a good stop over for shopping centres	Connected to all locations, access to metro stations (Rajendra Place and Karol Bagh) is convenient
Laxmi Nagar	East	Residential / Commercial	• This area is a residential colony in East Delhi situated on Vikas Marg • It is a well-established colony in the eastern part of Delhi, minutes away from Connaught Place • The locality is known for the shops, educational institutes and coaching centres located here • Known for its bustling market, people from various other localities like Mayur Vihar Phase 1 & 2, Indirapuram, Vaishali come here for shopping	Being located in central Delhi, it is well connected with the other parts of the city by trains, buses and public transports
Patel Nagar	Central	Residential	• Prime residential area with amenities like hospitals, schools, cinema halls and malls nearby • The area in close vicinity to Delhi's busiest market Karol Bagh and is only 8 km from CP	The locality has good metro connectivity
Yamuna Vihar	North East	Residential	• Well planned, residential colony with good amenities • Proximity to ISBT Kashmere Gate (~7 km), DU North Campus (~7 km) and Anand Vihar Train Station	• It is well connected by trains, buses and public transports

Divisions	Circle	Type of Area	Economic Profile	Connectivity
				• Connected to Outer Ring Road
Daryaganj	Central	Commercial	• Commercial hub with wholesale market of booksellers and publishers • It is open from all directions making entry-exit smooth • Close to Raj Ghat, Red Fort, Jama Masjid, Chandni Chowk • Close to wholesale markets like Lajpat Rai Market, Bhagirath Place, Dariban, Cycle Market, Meena Bazar and proximity to Firoz Shah Kotla Stadium	Good road and public transport connectivity

Using a detailed feasibility analysis, each of the shortlisted division was ranked and based on a composite score, the priorities for setting up a PCS was decided. The outcome is as shown below:

Table 72: Devising Priority of PCS Locations in BYPL Licensee Area

Division	Economic Profile	Connectivity	Public Spaces available	Proximity to Commercial Hotspots	Priority
Mayur Vihar	Medium	HIgh	High	Medium	P1
Shankar Road	Medium	High	Medium	Medium	P2
Laxmi Nagar	Medium	High	Medium	Medium	P3
Patel Nagar	Medium	Medium	Medium	Medium	P3
Yamuna Vihar	Medium	High	Medium	High	P3
Daryaganj	Medium	High	Medium	Medium	P3

Furthermore, in each location, major areas for prospective PCS installations have been mapped. While devising locations, few key points like type of surrounding area, availability of parking, economic strata of people visiting the place have been kept in mind.

Table 73: Tentative Locations in Shortlisted Divisions of BYPL

Division	Malls	Markets	Municipality Parking Lots	Metro Stations	Public Institutions/ Offices	Hospitals
Mayur Vihar	• Star City Mall • Galleria Mall	• Acharya Niketan Market • DDA Main Market	• Metro Station • Mayur Vihar 1 Metro Station • Mayur Vihar Extension	• Mayur Vihar 1 • Mayur Vihar Extension	Delhi Jal Board	Lal Bahadur Shastri Hospital
Shankar Road		Shankar Road Market		Rajendra Place		• Sir Ganga Ram Hospital • BLK Hospital

Division	Malls	Markets	Municipality Parking Lots	Metro Stations	Public Institutions/ Offices	Hospitals
Laxmi Nagar	• V3S Mall • Cinepolis	Laxmi Nagar Market	11 DDA authorised parking lots [single lane parking along roads]	Laxmi Nagar	East Municipal Corporation of Delhi Head Quarters	Makkar Multispeciality Hospital
Patel Nagar	Moment Mall		• Campa Cola Factory • Galaxy Toyota Near Moment Mall	• Patel Nagar • Rajendra Place Shadipur	• CSIR • National Physical Laboratory • Indian Agricultural Research Institute	Sardar Patel Hospital
Yamuna Vihar			• BYPL Grid Substation at Bhagirath • BYPL office		Directorate of Education, Delhi	
Daryaganj			• Ghata Masjid, under Building of Sales Tax • SDMC Parking Opposite B7 • Sanjeecan Hospital			

Additionally, railway station parking lots, bus depots, fuel stations of Oil Marketing Companies (OMCs) can be used as locations for setting up of PCS in the 6 divisions.

9.6.5 CAPEX Requirement

With charger cost contributing to ~80% of the total CAPEX for a PCS, it is important to assess its viability and usage before deciding on the type of installation required. Guidelines issued by the MoP in December 2018 dictates PCSs should have one or more electric kiosks/boards with installation of all charger models. Based on industry interactions and study author’s estimates, this would entail installation of five chargers and an upfront cost of INR 1.7-2.0 million.

Table 74: Typical Costs for Different Types of Chargers (Voltage Output, Current Rating)

Type of Charger	Power Output (kW)	Approximate Cost (Rs Thousand)
CCS	25	700-800
CHAdeMO	25	700-800
Type 2 AC	22	110-130
Bharat DC 001	15	200-300
Bharat AC 001	3.3	20-50
Total Cost		1,700-2,000

Additionally, close to INR 0.3-0.35 million will be incurred towards new electricity connection, grid up gradation (setting up new transformer, LT cabling, installing new panels, breakers, energy meter), civil works, deployment of EVSE software (for integration with chargers and payment gateway) and other miscellaneous costs.

Table 75: Other Costs Associated with Setting up a PCS

Parameters	Approximate Cost (Rs Thousand)
New electricity connection and grid up gradation cost	200
Civil works	75
EVSE management software	30
Miscellaneous cost	25
Total cost	330

This leads to a total CAPEX of INR 2.0-2.4 million. Assuming that the land will be taken on lease, land costs have not been included in CAPEX. Power outputs for DC fast chargers have been considered to be 25 kW (and not 50 kW), taking into consideration high costs and lack of large battery powered EVs in the Indian market. However, going by the MoP notification and the EoI issued for setting up EVCSs in cities, DCFCs need to have a minimum power output of 50 kW. This would lead to an additional burden of INR 0.7-0.8 million per charger model.

In the current market scenario, where EV sales have not picked up in the country and proliferation of e-four wheelers is at least five years away, PCSs with all charger models seem to be unviable. However, government support, in the form of subsidies and grants, can drastically bring down costs. The GoI may initially take the subsidy route to develop the bare bone charging infrastructure with the hope that EV sales will rise and private entities will find the PCS business attractive, driving the market forward.

Using the charger requirements set out in the EoI issued by the DHI for PCSs in Indian cities, the approximate CAPEX comes close to INR 4.35 million. With 50% government subsidy, it leads to an upfront cost of ~INR 2.22 million.

9.6.6 Financial Viability of Charging Stations

The financial viability of a charging station depends on:

1. Upfront cost of setting up a station
2. Station utilisation
3. Federal, state and local government support in driving the charging station's overall viability

Assuming that EV adoption will pick up pace in the next decade, the utility has already determined the number of PCSs that need to be set up in its licensee area along with the prospective locations. The next major hurdle for the utility is to assess the viability of setting up charging stations. Financial viability can be determined using two parameters:

1. Capacity utilisation factor of the charging station
2. Margin on electricity tariff

The capacity utilisation factor (or demand-side driver) is the most important parameter that can make or break a PCS's success. Sound location planning and business model planning are paramount to alleviate this risk.

Cash flow simulation has been used to assess the viability of setting up a PCS in India. It is based on the following assumptions:

1. The PCS has three fast chargers and two slow chargers, as per the guidelines and standards set by the MoP in December 2018
2. No cost of debt has been considered for model simplicity
3. Electricity tariffs at delivered point of the PCS are passed on to the EV charging user
4. Grid upgrade costs in lieu of EVCS set up, are not passed on to the consumer

The model takes into consideration the following CAPEX and OPEX components:

Table 76: CAPEX and OPEX Components Considered by the Model

CAPEX	
1	Charger cost
2	New electricity connection, transformer, cabling (100 m), panels, breakers, energy meter
3	Civil works (flooring, boards, painting, brandings, shed/ cover, etc.)
4	EVSE management software - Integration with chargers and payment gateway
OPEX	
1	Technicians (1 technician @INR 25,000/month for first 6 months)
2	Site maintenance staff (1 personnel @INR 15,000/month throughout year)
3	Network service provider fee
4	EVSE management software fee (10% of net margin on electricity charges)
5	Payment gateway fee (1-2% of total money collected)
6	Land lease rental
7	Advertising cost

Using the CAPEX costs calculations for setting up of a PCS using 6 chargers (3 fast chargers and 3 slow chargers) as set out in the recent EoI by DHI for PCS installations in Indian cities, it was found that a charging station is not viable in the present scenario. The assumptions used to derive financial viability are given below:

Table 77: Assumptions Taken for Financial Viability

Power Sold Projections	Year 1	Year 2	Year 3	Year 4	Year 5
Utilisation levels of PCS	15%	25%	40%	40%	50%
Margin on Electricity Tariff (Rs./unit)	2.5	2.5	2.5	2.5	2.5

Using the aforementioned assumptions and forecasting cash flows, the flowing outcome is deduced:

Table 78: Scenarios Developed from the Assumptions and Forecasted Cashflows

	Level of Subsidisation	IRR (for 5 years)
SCENARIO 1	0% of EVSE subsidised	-25%
SCENARIO 2	50% of EVSE subsidised	-14%
SCENARIO 3	70% of EVSE subsidised	-5%
SCENARIO 4	100% of EVSE subsidised	36%

9.6.7 Business Models for Setting Up EV Charging Stations

As discussed earlier, the major impediments to EV charging station development are high upfront cost and inadequate charging station utilisation. While the former can be alleviated through upfront federal subsidies, the second challenge is more fundamental in nature. Governments across the world dole out financial incentives to market makers during the technology adoption phase in the hope that these will have a knock-down effect and lure more people to adopt the technology. Therefore, the government intent is paramount in developing the EV charging infrastructure. However, initial traction in EV sales and charging station development is not expected to set the ball rolling. In developed economies like the US and Europe, EV owners use public charging for only ~5% of their total charging requirements. This poses a challenge for nascent EV markets like India, where utilisation will be very low in the initial stage. Therefore, direct revenue streams from PCSs are not enough to earn investor payback. Additionally, the uncertain demand from a station can bode additional risks to the PCS.

Under the current market conditions, it is unlikely that the initial investment will be recovered within the investor's preferred duration of five years, by relying solely on direct revenue from the provision of charging services. Following business models can help enhance the financial viability of charging station projects in India:

CAPEX-Side Interventions

1. Grants: Public grants can significantly lower the upfront cost of a charging station project and allow an owner-operator to achieve an attractive payback.

2. Low interest loans: State governments' access to low-cost capital, through either interest subvention or greater credit cycles, can improve the financial performance of PCSs.
3. EV incentives: Vehicle incentives can aid the growth of the EV market, and thus increase charging station utilisation. Increasing usage will make PCS projects profitable.

Revenue-Side Interventions

1. Sales boost: This model is based on the partnership between a charging station developer and an automaker. Under the terms of agreement, the automaker, which benefits from the improved access to EV charging, subsidises the deployment of the charging network. The automaker and the charging network developer jointly promote EV usage through advertising and awareness programmes. The degree of subsidisation is decided based on the agreement modalities and the targets met.
2. Revenue sharing: In this model, a group of businesses located in close proximity (in case of tourism or shopping destination, commercial centre) contribute to a funding pool that provides an annual subsidy to a charging network owner-operator. The assumption is that the deployment of an EV charging system in the area will boost footfalls and therefore, revenue. The group of businesses annually share a percentage of their increased revenue with the charging service provider, thereby increasing the owner-operator's revenue.

Utility Investment Models

Utilities can invest in EVSEs ranging from partial to full ownership. The modalities of each investment model are explained below:

Business Model	Modalities	Pricing Mechanism	Risk
Make-ready	The utility invests in 'make-ready' installations by providing electrical infrastructure (wiring, cabling, transformer setup, etc.) required for EVSEs. The utility does not own or invest in the EVSE components, and its responsibility is only restricted to network upgrades, as deemed necessary to make power available to the host site	As determined by the electric utility and approved by the state commission for supply of power to EV charging stations. In case a separate category of EV charging stations is not carved out, tariff as determined for the relevant LT category in the state, will be applicable. As per the MoP guidelines, the tariff should not be more than 15% of the average cost of supply (ACS) of the state	Minimal
Rebates for EVSEs	Utilities provide host sites with financial incentives such as rebates for the costs of the EVSEs and/or the make-ready infrastructure portion. This reduces the upfront EVSE cost for all developers and customers. PCSs can be incentivised based on certain EVSE	Price payable to the utility will be as per the determined tariff. Delivered cost of power will be payable to the owner-operator. As the model does not entail a long-term partnership, no revenue-sharing mechanism is applicable	Moderate. Although the utility has borne a part of the CAPEX (through discounts/ free infrastructure upgradation/ making land available) in the anticipation that higher

Business Model	Modalities	Pricing Mechanism	Risk
	functionalities like two-way communication with the utility. This model helps reduce risks without the utility getting tied into long-term partnerships		power sales in the form of EV charging will follow, business conditions may not turn out to be as expected. This exposes the utility to unrecovered and sunk cost
Public-private partnerships	This entails a joint exercise between two entities in PCS development. It brings in the expertise and experience of both parties, while diversifying risks and sharing costs. Each entity covers a portion of the infrastructure cost, as mutually agreed, through a joint venture or a special purpose vehicle. Such an arrangement can be critical to reduce risks and have access to lower cost of capital due to implicit government support in the public entity	Delivered cost of power from the EVCS will depend on the station utilisation levels. However, high prices, to recover costs (owing to low sales), will not be justifiable in the Indian context	Moderate. With marginal exposure in the project, the utility has some level of comfort and protection
Owner and operator	The utility engages in electric grid enhancements and upgrades as well as full build-out and operation of EVSEs at host sites. This helps the utility to reach out to its consumer base in its licensee area, which fosters trust and accountability. With a single entity building and owning the EV charging infrastructure, operations are streamlined	Delivered cost of power from the EVCS will depend on the station utilisation levels. However, high prices, to recover costs (owing to low sales), will not be justifiable in the Indian context	High. Underutilised PCSs can result in stranded cost for utilities, putting public money at risk

While the federal and state government's role in giving the initial push to public charging infrastructure is critical, private investments can also accelerate the development. Public investments can help improve the viability of charging infrastructure projects in the short run. This needs to bring in more private participation as the market begins developing at a faster pace.

Cost Recovery for the Utility

1. **From EV charging consumers**: The biggest and most significant way of cost recovery is from EV owners who charge their vehicles via PCSs. Cost payable to the electric utility will depend on the model adopted. In case of the *owner-operator model*, the delivered cost of power at the PCS needs to be worked out by the utility. The charging cost at a station (in the form of premium charged over the cost of electricity) is an important piece of the puzzle. The cost of charging at a PCS is significantly higher than at home. Although the benefits offered, in terms of minimising range anxiety, are significant, consumers' willingness to pay for public charging is important. The price at which power is delivered

at a PCS can make or break its financial viability. As per a study conducted on PCSs along the West Coast Electric Highway in the US, when several Level 2 and DC fast charging stations, which were earlier free for public use, began levying fees, consumers immediately reduced EV charging at PCSs and changed their charging patterns completely. This suggests that when required to pay a fee for charging at PCSs, users will not charge their EVs unless they are forced to. Therefore, the pricing of electricity must be done judiciously, and charging locations should be well interspersed such that utilisation levels are high.

Different utilities across the world have been using innovative fee structures for their charging units. The fee structure typically includes one or more of the following components: energy-based fee, monthly subscription fee, per-session access fee, and time-based fee.

Rate designs need to be devised in such a way that utilities can influence charging behaviour, and in turn, minimise costs to operate the distribution system (peak load demand mitigation) while maximising economic benefits. For states with high renewable generation, utilities can manage loads in a way that coordinates peak RE generation with increased EV charging, thereby using excess power to service additional load and reducing curtailment. The optimal pricing structure will vary from location to location based on a number of site characteristics, including anticipated utilisation, charger type, and ownership of charging station (site owned/ utility owned).

2. **From the EVSE host**: This is applicable when the utility has invested in PCSs via the *public-private partnership model.* With the utility sharing capital expenditure with another entity, the former is liable to share revenue with the latter based on the 'percentage of total' method. Although this route of recovery has higher upside in case of strong station utilisation, the utility is also exposed to downside risks, owing to sub-optimal station utilisation and longer payback period.

3. **From electricity consumers**: This is mostly used when the utility invests in PCSs through the *make-ready or PPP mode*. Recovering costs from consumers through standard, set rates is a well-established utility practice, employed for the development of the renewable energy and energy efficiency markets in all developed markets. Cost recovery from consumers over a long tenure is a useful tool to overcome uncertain revenue potential from PCSs. Recovering costs through power customers, rather than directly from EV charging customers, also helps lower the barriers to EV adoption. However, in a regulated market like India, such cross subsidisation and cost escalation may not be suitable and will be subject to the state commission's approval.

Source of Funds for the Utility

While the utility files a tariff petition by predicting load growth and power purchase requirements for its conventional business (i.e. power sales), the charging station business entails different business models, revenue streams and CAPEX requirements. In the initial phases, when the electric utility will invest in make-ready PCS installations (by setting up necessary network augmentation, distribution transformers, meters), it can include the associated costs in the multi-year tariff (MYT) petitions as it has been doing now. However, investments made through PPP mode or owner-operator mode would require change in business modalities for the utility. Subject to approvals from regulatory authorities, the utility can raise money either through internal accruals or from private investors. However, till the PCS business becomes a self-sustaining business area for the utility, funds need to be obtained through grants, loans from banks or through strategic investors, like private equity (PE) players. As the PCS business churns more revenue, incremental CAPEX can be invested through realised profits.

Business Models for Setting Up PCSs in India

A PCS is not viable in India presently. With a miniscule number of EVs on the road, the capacity utilisation factor of a charging station is not expected to be greater than 5%, even in the most conservative scenario. No level of government support (sops or subsidies) can enhance project viability. Many public sector companies (e.g., NTPC, EESL), private companies (e.g., Vakranjee, Amara Raja), and private utilities (e.g., Tata Power, BSES Yamuna) have set up PCSs on a pilot basis, mostly for demonstration effect. However, utilisations are low and unattractive. The GoI has been taking steps in the right direction to bolster EV sales through FAME subsidies and a phased manufacturing programme. However, with the slowdown in the automobile sector, manufacturers are expected to go slow on EV programmes. Even if EV sales does pick up, mostly two-wheelers, three-wheelers and buses will be the biggest contributors, which do not necessarily require PCSs. E-passenger vehicles, which need PCSs, are not expected to catch up before 2025. Therefore, the modalities of business model need to be assessed carefully.

Based on international best practices and industry views, the following business models may be considered by federal agencies/ public companies/ private entities:

1. Grants and subsidies from the government, to reduce CAPEX towards station deployment
2. EV owners to pay a monthly fee to EV manufacturers that will be bundled in the initial cost of EVs
3. City governments / municipalities / highway authorities may be mandated to allot space on long lease at concessional rates/ for free
4. Bundle EVCSs in new buildings making it mandatory for residential/commercial centres exceeding a certain built-up area. The impact of EVSE infrastructure cost as a proportion of total per square meter cost of buildings will be negligible
5. EVSE infrastructure may be clubbed with highway construction cost – again it will have a negligible impact on per kilometre cost of highways
6. Oil distribution companies may be mandated to create EVSE infrastructure in their retail outlets
7. Public sector undertakings and large private companies (above a certain turnover) may be mandated to set up (or contribute towards) EVSE infrastructure in their area of operation

8. EV manufacturers consortiums may promote EVSE networks and collect monthly subscription from EV owners and pay to the EVSE owners and operators
9. Fleet operators and car rental companies may be allowed to set up EVSE networks
10. Allot land and licences to set up large EVSE stations at strategic locations, which will have other facilities like café, gaming stations, convenient stores and grocery/vegetables shops. Revenue generation from the entire commercial centre can be aggregated, covering the costs of EVCSs

9.6.8 Final Outcome

Although PCS is a new and lucrative business opportunity, it is fraught with risks and uncertainties. In a country like India, where the automobile sector is entirely ICE-driven with no established ecosystem of EV, neither from the manufacturers nor from the consumers, EV is still many years away. Furthermore, with negligible battery manufacturing base in the country, the case of domestic manufacturing is still elusive. The auto industry, which contributes close to ~ 8% of the manufacturing GDP of the country, is experiencing a worst slowdown in two decades. Any forward-looking policies, on behalf of the government to speed up e-mobility is now in the backburner, owing to slack in sales from the segment and risk of further disrupting the segment from forward-looking EV policy, which is not exactly the need of the hour. Therefore, uptick in EV sales in the country is going to be gradual, at best. Utilities like BYPL need to assess market risks judiciously and adopt the best business model suitable for PCS to keep sunk costs to the minimum. Some of the major risks hogging the PCS business are as given below:

Table 79: Major Risks for Public Charging Station Business

Sr. No.	Risk	Outcome	Impact
1	Differential of electricity and gasoline prices rise	Low running costs of EV vis-à-vis an ICS; adoption improve for EV	Positive
2	Improvements in battery technologies	Reduction in upfront costs of EVs	Positive
3	Lack of indigenisation and domestic manufacturing of EV/ EV parts	Transition from ICE based Indian auto industry to EV to take longer	Negative
4	Low station utilisation	High stranded costs of PCS	Negative
5	Lack of subsidies by the government towards PCS	Sluggish development of bare bone PCS infrastructure	Negative
6	Lack of federal support in the form of conducive polices	Slacking of investor sentiment, sluggish development of PCS	Negative
7	Lack of private investment in the PCS space	PCS as a business do not scale up	Negative
8	High cost of funds, lack of financing options for setting up of PCS	Prohibitive CAPEX costs thereby hampering investor sentiment	Negative
9	Improvement in battery swapping ecosystem	New business opportunity; to enable faster EV adoption in 2W, 3W and e-bus space	Positive

The recommended roadmap, as suggested, is given as below:

Phase 1 (FY20-FY24): Traction in EVs is expected to be slow with the majority of incremental sales coming from 2W and 3W. As discussed earlier, the two segments do not necessitate PCS installations as majority of the charging takes place at home or at workplace (for those commuting to office in e-2W). Some charging may require PCS, especially from 3W segment (if charged inside business hours) or from 2W (if used to travel long distances, like intercity tours). In both cases, consumers will prefer DC charging requirements as the role of PCS would be for quick top-ups such that the EV owners can continue their onward journeys without significant delays. PV segment is not expected to make any significant headway while e-buses may show traction, majorly owing to government STU's auctions from procurement of electric buses.

<u>Role of BYPL:</u> With station utilisation questionable and risky, PCS installations under the owner-operator model should be avoided. In strategic locations, where congregation of EV (either natively or incoming from other areas), is expected in the early stages, the utility can look at setting up PCS, either through the PPP mode or by making strategic investments in make-ready installations. Probable locations to look at are Mayur Vihar and Shankar Road due to strong possibilities of the places being early EV adopters. The utility may look at participating in tenders for PCS installations floated by the Central or state government in order to avail subsidy benefits. This will help reduce high CAPEX costs as well as position the utility in being an early mover in the PCS space. The battery swapping ecosystem, despite nascent presently, may evolve due to government push and industry interests. Although a typical battery swapping station (BSS) involves the partnership between a vehicle manufacturer and battery maker, the utility can look at strategically investing in BSS installations, if a business case exists.

Phase 2 (FY25-FY30): More accelerated development of EVs is expected as cost economics become conducive and vehicle manufacturers bring in more products in the market. Consumers will become more likely to take the EV jump as the overall ecosystem improves. Battery technologies will mature and costs will plummet (Li-ion battery pack prices expected to reach ~$116/ kWh in 2030 from $230/ kWh in 2018) making EV products more competitive and suitable for the masses. The 2W and 3W will continue to be frontrunners in EV sales, while PV and buses will begin the electric transition faster than before. The commercial segment (fleet taxis) and intra city buses will show strong growth owing to federal push.

<u>Role of BYPL:</u> The utility can look at investing in the PCS space more aggressively with reduction in CAPEX costs of chargers and more certainty in station utilisation levels. The owner-operator route may be explored in strategic locations where charging requirements are expected to become high. In other locations, PCS installations through the PPP mode can be a safe bet. As the market matures, government subsidies on PCS will subside allowing the market to drive itself and discovering prices based on dynamics. The PCS set up in Phase 1 shall see higher utilisation levels. The rise in revenue from the old stations can

be utilised in setting up newer stations. The premium charged on electricity prices (delivered cost) from the high-utilisation stations may be kept slightly higher to support the new stations till the time the latter become self-sustaining. As a second option, a part of stake in the older stations may be divested to fuel more CAPEX towards newer stations, allowing the utility to drive its PCS business as a self-sustaining unit.

BYPL can engage in advertising activities to promote EVs in collaboration with auto manufacturers on a revenue sharing mechanism. Different digital as well as print media options needs to be looked at for a holistic engagement program.

9.6.9 Organisational Capacity Planning

Before entering the EV charging station business, it is important that the organisational structure and processes of the utility are aligned towards achieving the e-mobility goal. The organisational structure needs to take into consideration the following facets:

1. Legal and regulatory framework of the organisation
2. Incentive system
3. People management system

The conventional scope of utilities does not align with the PCS business. However, with the market moving towards faster adoption of EVs, it is in the interest of the utilities to expand beyond the conventional power distribution business. This requires business repositioning and diversification, and re-assessment of the organisational structure to focus on new value pools.

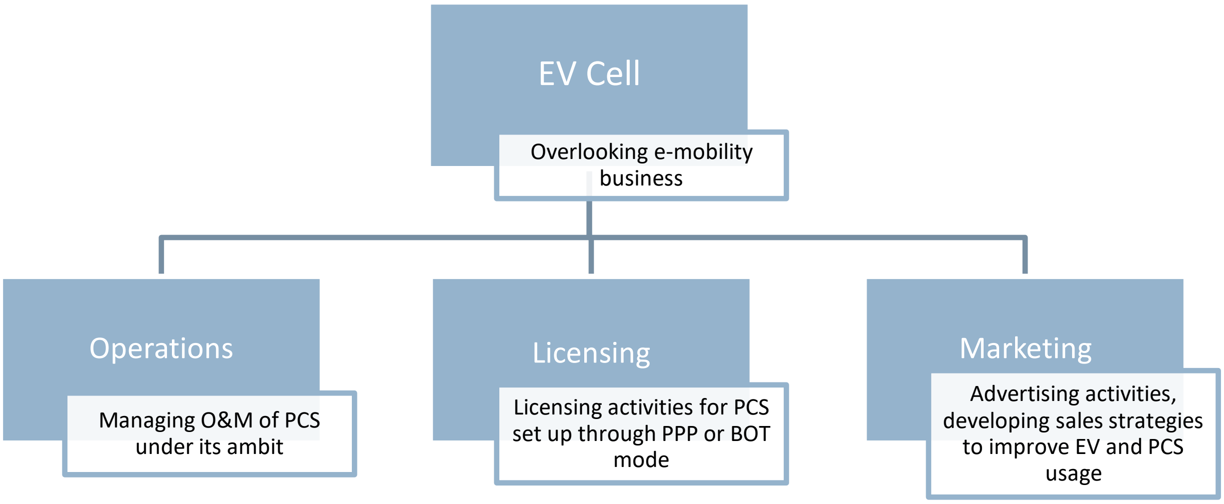
Internationally, utilities have carved out a different vertical overlooking the EV business as they consider e-mobility to be a core business area. The vertical, majorly an unregulated business in most advanced economies, is kept separate from the other conventional and regulated businesses. The leadership team closely monitors the EV vertical, and performance measures have been put in place by allocating financial targets. New talent, with experience in the EV space, is hired to drive the business.

However, in India, the ecosystem is completely different. The role of utilities in the EV charging space is still being worked upon, and the sector continues to face several regulatory hurdles. Though a few utilities are watching the space closely and some pilot projects have been launched by BYPL and Tata Power, distribution utilities in India are yet to set up a full-fledged business based on PCS development.

The organisational structure of the utility needs to be rejigged to align resources and skill sets towards the new areas of interest. We do not propose creating a new vertical for EVs and e-mobility at present as it is a niche market. Utilities in the country are still studying the sector in terms of viability and business interest. Therefore, a carve-out at this juncture does not make economic sense. We however propose creating a new horizontal under the operational portfolio of the utility, which will look after new energy business areas like distributed generation, energy storage and e-mobility. As e-mobility becomes a more sustainable business area, it can be carved out into a new vertical.

The organogram for the utility overseeing the EV and e-mobility business areas is as follows:

Figure 28: Suggested Organogram for BYPL



Will/ Vision/ Strategy of Management

BYPL intends to be amongst the most admired and most trusted integrated utility companies in the world. It also focuses on delivering reliable and quality products and services to all customers at competitive costs, with international standards of customer care- thereby creating superior value for all stakeholders. The distribution utility does not have any vision or mission focused on EVs or e-mobility. However, in its mission statements, the company has set its focus on environment along with other stakeholders.

Staff Exposure and Expertise of EVs

At the current juncture, BYPL has no intentions to enter into EV charging business directly. Instead, it is facilitating setting up of chargers in its licensee area by interested parties. In that endeavour, it is undertaking capacity building and is in the process of recruiting close to 200 employees with relevant technical background (150 in junior management and 50 in middle management). The junior management is into extending connections, visiting sites, approving the sites, organising installation of EV charger while the middle management is into regulatory approvals, business development and improving enablement. Presently, there is no organization planning which has been made to undertake promotions for EVs.

10 Country in Focus: Pakistan

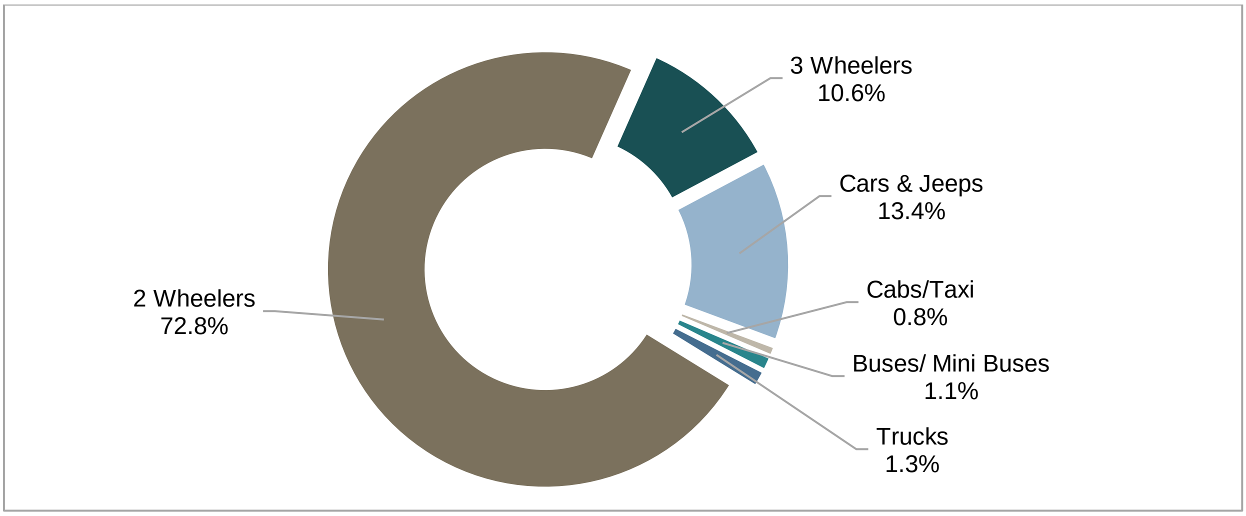
10.1 Present EV Sales and Charging Infrastructure

The transportation sector is critical Pakistan's economy as it contributes ~10% to the country's GDP. The country's total road network is ~264,401 km, including national highways, motorways, expressway and strategic routes. Roads are the predominant mode of transport in Pakistan, accounting for over 92% of passenger and 96% of freight traffic. According to National Transport Corridor Improvement Program (NTCIP) objectives, the National Transport Policy aims to provide a safe, reliable, effective, efficient, affordable, accessible, sustainable and fully integrated transport system that meets freight and passenger mobility requirements. It plans to offer improved services in a cost-effective way that supports the government's goal of increasing public welfare through economic growth, social improvement, poverty reduction and infrastructure development, while being environmentally and economically sustainable.

In the last five years, the transport sector has been transformed by a road network expansion, and building of new motorways and mass transit systems. The country has three operational Bus Rapid Transit (BRT) corridors in major cities i.e. Lahore, Islamabad-Rawalpindi and Multan[18], with a total length of 70 km, and catering to more than 400,000 passengers every day. Three similar projects are under construction and more than 80% work has been completed on all three projects. These new corridors are in Peshawar, Karachi and Islamabad (phase II) with a total length of 165 km and will cater to ~530,000 commuters daily.

By 2018, 21,506,641[19] motor vehicles were estimated to have been registered, of which the major share is of two-wheelers, followed by cars. A breakup of the registered vehicles (2018) has been depicted below:

Figure 29: Total Number of Motor Vehicles Registered in Pakistan



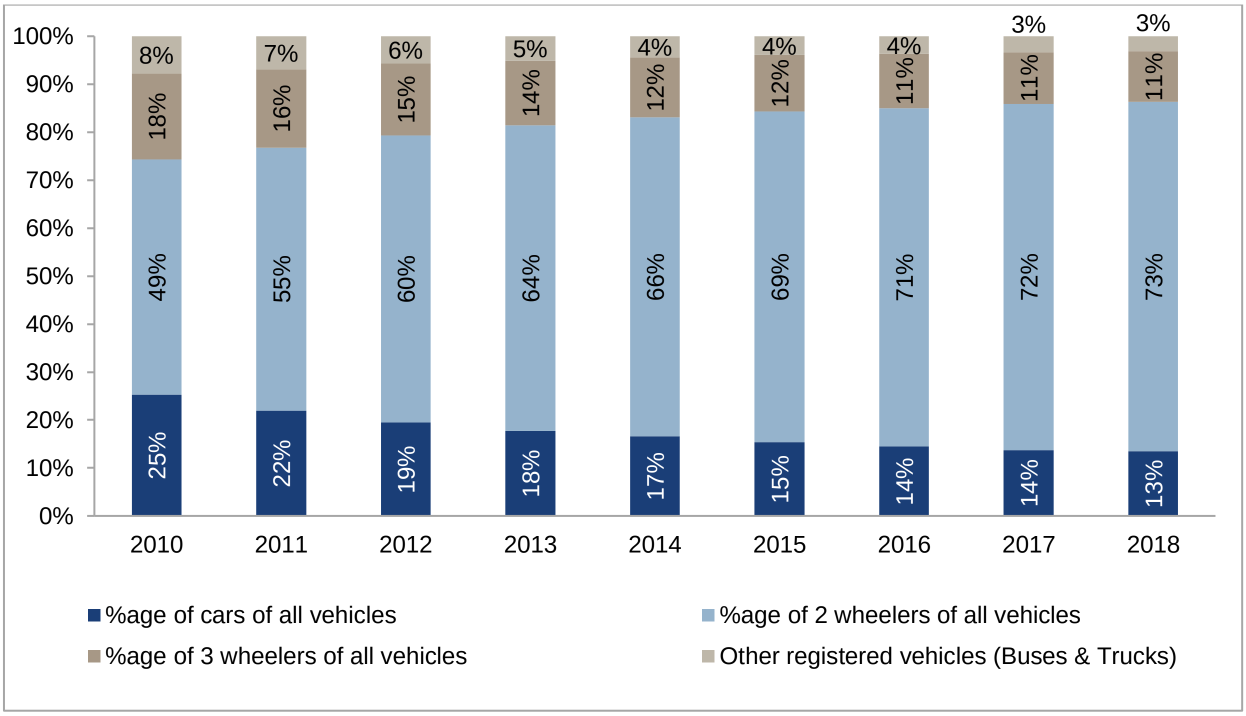
Source: Pakistan Automotive Manufacturers Association (PAMA)

[18] Punjab Mass Transit Authority, https://pma.punjab.gov.pk

[19] Pakistan Automotive Manufacturers Association (PAMA)

As seen in the figure above, two-wheelers dominate the total number of registered vehicles in Pakistan, with cars & jeeps only constituting 13.4 % of the same. The figure below shows the trends in adoption of types of vehicles over the last eight years (2010 – 2018).

Figure 30: Percentage Distribution of Vehicles in Pakistan

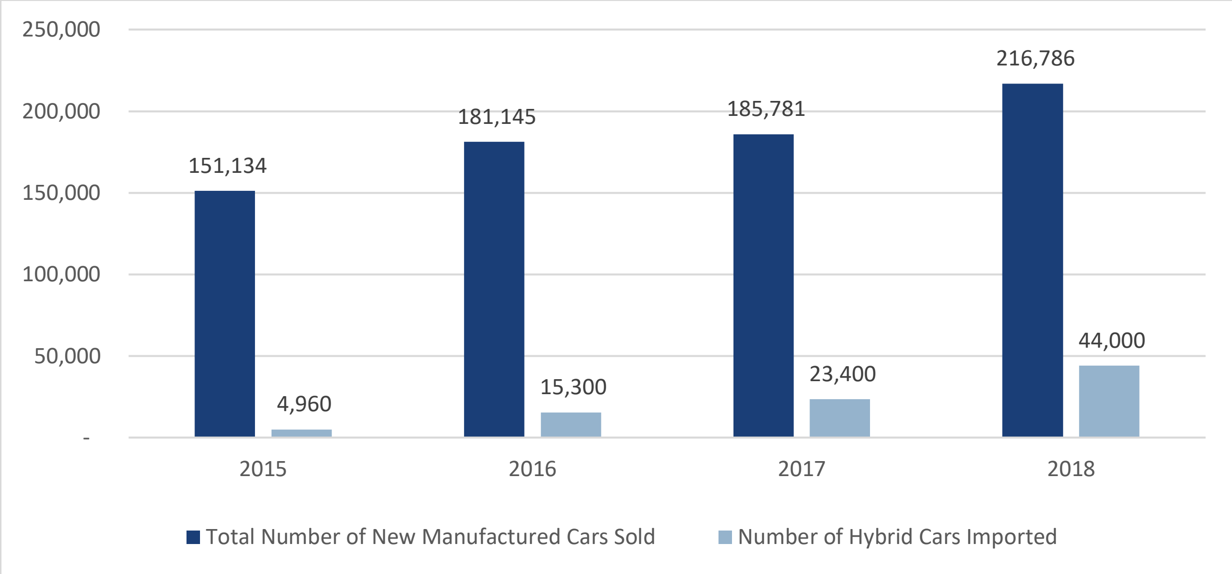


Source: Pakistan Bureau of Statistics, Statistical Yearbook 2018

It is also evident from the figure above that the penetration of two-wheelers is increasing rapidly, mainly due to the support for local bike manufacturers. In the case of cars & jeeps, the absolute number is increasing while the overall percentage is decreasing. Over the last eight years, cars and jeeps have accounted for an average 17.6% of all registered vehicles in Pakistan. For cars and jeeps, only three manufacturers monopolise demand; other manufacturers have very limited penetration. Over the years, used Japanese cars have gained traction in urban centres, as these used cars are better equipped and have better safety features as compared to the local manufactured cars in Pakistan.

EV readiness is a community-wide effort, requiring planning, charging infrastructure, policies, support services, etc. There is no way to accurately predict the exact number of EVs or Plug-in Hybrid Electric Vehicles (PHEV's) that will be operating in Pakistan in the next two or five years or to estimate the potential future charging needs. One approach to predicting future EV demand is to analyse the experience of hybrid vehicles and their early adopters. Hybrid vehicles have gained traction over the past five years due to government subsidies in taxes and duties. Consumer inclination towards PHEV is slow because of the capital associated with it, but a few PHEVs are still seen on roads. Pakistan's market is opening up as almost all the auto manufacturers globally have started producing cost-effective electric cars. The graph below shows the statistics of local cars versus used hybrid cars imported each year.

Figure 31: Locally Manufactured Cars vs. Imported Hybrid Cars



Source: Pakistan Automotive Manufacturers Association (PAMA)

Currently, the imports of hybrid cars constitute more than 70% of the vehicles imported into Pakistan. The above graph shows the exponential increase in import of hybrid vehicles. In the case of plug-in hybrids or full electric vehicles, the numbers are not very promising. Till June 30, 2019, a total of only 250 plug-in hybrids and full EVs were registered in Pakistan. Of these, 90% were plug-in hybrid[20] cars.

BMW has tried to set up EV charging stations in seven cities[21] across Pakistan. Three of them were installed and others are planned, and one of them was in the Islamabad Electric Supply Company (IESCO) region. The charging stations are only for BMW consumers and free of charge. The set-up cost and operational expenses are borne by BMW dealership (Dewan Farooque Motors). No other public charging stations are currently installed or planned.

According to global trends, hybrid car owners are early adopters of plug-in and full electric cars. Recently, Hyundai launched its IONIQ electric model in Pakistan which has been received well. Another MoU has been signed between Rahmat Group and BYD China for assembly and manufacture of EVs in Pakistan. According to available information, various EVs, including buses, passenger cars and vans, as well as batteries, chargers and related components will not only be made for Pakistani market, but will export to the region as well. These statistics support the growth and adoption of EVs in Pakistan. Apart from cars, we do not see much traction for two and three-wheelers in Pakistan. There is also news that the Khyber Pakhtunkhwa provincial government plans plug-in hybrid busses for the mass transit system in Peshawar[22].

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[20] All Pakistan Motor Dealers Association (APMDA)

[21] Dewan Farooque Motors, Pakistan

[22] Peshawar Bus Rapid Transit 2019

10.2 Regulations and Federal Policies Driving EV Adoption

The regulatory status of the EV charging infrastructure has been indicated in the Pakistan's first EV policy 2019, but it only indicates the subsidies on import of EV charging equipment. The policy is still not very detailed to cover different aspect of the EV market. Electric utilities and other stakeholders foresee a number of issues relevant to EVs and grid planning that is important to consider as EV infrastructure grows. Policy formulation is the key driver for the EV market to take off, and all stakeholders concerns need to be addressed in the policy at large.

According to the Auto Development Policy 2016-21 [23], the federal government has announced an exemption on customs duty, sales tax and withholding tax on import of hybrid electric vehicles (HEVs) falling under Pakistan Customs Tariff (PCT) Code 87.03, up to 50%. To support the uptake of EVs, there is an exemption of 50% customs duty and taxes on import of HEVs up to 1800 CC, and 25% on HEVs exceeding 1800 CC. Even in the new EV policy it is stated that, the policy of EV import will remain intact as per Auto Development Policy 2016-21. Only the support to local manufacturers is indicated in the new EV policy.

In May 2019, the prime minister of Pakistan announced a target for EVs to constitute 30% of total vehicular traffic by 2030. The Ministry of Climate Change was tasked with drafting an action plan to achieve the said target. The draft EV policy has been approved by the cabinet. According the press release of the Ministry of Climate Change[24], the EV policy is focused on offsetting the emissions from the transport sector. The first phase will be focused on the two and three-wheeler market segment. The implementation is expected to start from two cities i.e. Islamabad (federal capital) and Sialkot.

Regulatory authority or distribution companies have yet to work on policy for the development of the EV market. No tariff regimes or incentives for early adopters have been worked out. Load flow studies and required planning to accommodate the power requirement for charging has yet to be done by DISCOs.

While global EV sales remain low, only in a few countries have EVs gained traction. Countries that gained traction have four common indicators that helped them adopt EVs. These indicators may also help in determining the pace of EV penetration in Pakistan.

Regulations & Incentives

While early adopters of EVs encouraged e-mobility through a range of incentives, these alone did not drive EV penetration. They provided a supportive environment that established strict regulations on carbon emissions, indirectly stimulating the higher adoption of EVs. In fiscal 2019, the government allocated a subsidy on import of EVs, their associated components and charging infrastructure equipment. On the

[23] Pakistan Auto Development Policy 2016-21
[24] Ministry of Climate Change, Pakistan. www.mocc.gov.pk

instructions of the Prime Minister, the Ministry of climate change has been given directives to formulate a roadmap for 30% EVs by 2030[25].

Technology

As a large component of overall EV cost, high battery prices influence manufacturing and sales. Technology improvements help reduce battery costs, increasing efficiency and driving range, making EVs more accessible and attractive to potential customers. Two manufacturers, Hyundai and BYD, have signed MoUs to manufacture EVs in Pakistan. According to the MoU of BYD, they will not only produce for Pakistan's market, in fact this manufacturing unit will supply EV's in neighbouring countries. Local manufacturing units will help in cost reduction and technology upgrades, as per to local requirements.

Infrastructure

Easy and affordable access to charging infrastructure, both standard AC and rapid DC charging, is key to supporting the growth of EVs. Distribution companies, private investors and auto manufacturers will have to play their role in developing the charging infrastructure. On the other hand, the government also needs to outline policies that support all the stakeholders in development of a charging network for EVs.

Customer Demand

Creating a compelling cost proposition will be critical in encouraging customers to invest in EVs. The government may offer rebates on capital cost to encourage the early adopters. Annual renewal fees may be waived and credits in terms of tax exemptions provided to encourage people to opt for EVs

10.3 Outlook on EV Sales

The transport sector in Pakistan is growing at a double-digit rate due to a number of factors. The overall population in the country is growing at an annual growth rate of 2.1% Currently, Pakistan is going through rapid expansion in the network of highways (motorways and expressways). The commencement of China-Pakistan Economic Corridor (CPEC) has revitalized the construction and rehabilitation of the network of highways under the 'belt and road' initiative. Cumulatively, the aforementioned factors will add tremendous burden on the existing road network. The density of cars per 1,000 people in Pakistan is 14[26]. This number is estimated to reach 22 cars per 1,000 people by 2030. Additionally, various international automakers have also discerned such projected increase in number of vehicles. Over the next few years, up to 10 new automobile manufacturers have plans to install their production units in Pakistan that include Hyundai, Renault and Kia Motors, of which two manufacturers intend to produce electric vehicles. Introduction of new automobile manufacturers, accompanied by an escalating expansion in the network of highways and rapid urbanization, are bound to increase the number of automobiles in the country.

[25] Ministry of Climate Change, Pakistan. www.mocc.gov.pk

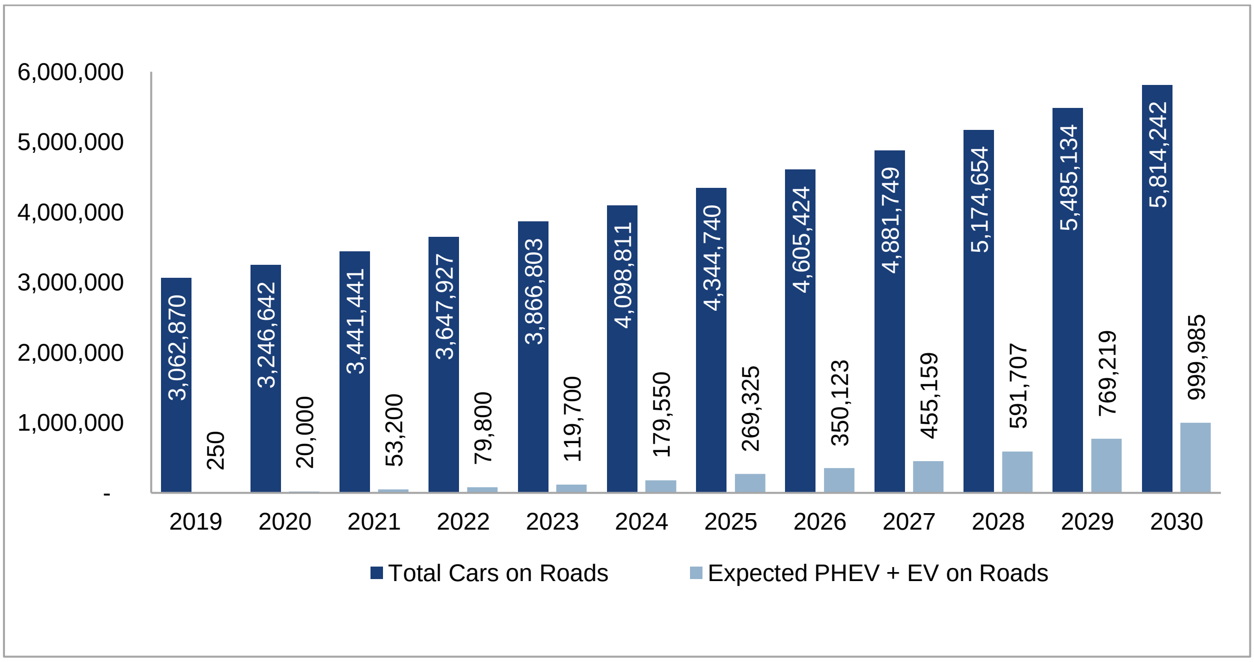
[26] Pakistan Automotive Manufacturers Association, PAMA Statistics 2019

Currently, the total number of vehicles on roads is 21.5 million (cars, bikes, buses and trucks), of which 2.9 million are cars. The total number of vehicles is estimated to reach 63.5 million by 2030, with only 5.6 million cars.

With the increase in population, consistent GDP growth, increase in foreign direct investment and new auto manufacturers coming in, conservative estimates show that Pakistan will have about 1 million electric vehicles by 2030. Of these one million EVs, 90% will constitute cars/jeeps/SUVs. The rest will be 2-3 wheelers and a small number of hybrid busses for mass transit. These 90% electric cars will be about 15% of total cars by 2030. The estimations are based realistic figures and indicators. Apart from these indicators, the government bought a fleet of 1,000 hybrid cars for highway patrolling police and intends to procure 65 hybrid busses for the Peshawar BRT. Such initiatives also aid to achieve the milestone of 1 million EVs by 2030. According to import statistics, a few units of electric bikes and rickshaws are being imported every year over the past 10 years, but they have not been able to make a market. The reason for such a low number of two- and three-wheeler penetration is their low range and mileage on full charge. As a result, the estimates show low penetration.

Based on the estimated statistics, we see that almost 6 million cars will be on roads by 2030 in Pakistan. As the country is still a virgin market for plug-in hybrids and full-electric vehicles, in the next two to three years, we do not see much traction for EV adoption. But as time passes, the government should plan and announces clear policies and targets for EVs, as a result of which EVs should get better traction in the coming years. The below graph shows how EVs will gain traction over years in Pakistan.

Figure 32: Projection of Cars on Roads of Pakistan by 2030



Source: Pakistan Automotive Manufacturers Association (PAMA)

The figures shown above are estimates based on previous data trends and policies for import and new manufacturers coming in Pakistan. Initially we see very few EVs in coming years as it will be totally based on imports. As new entrants for manufacturing of EVs start production in Pakistan, the EV sector will grow by 40% annually from 2022 onwards according to their production capacities. By 2030, electric cars will constitute around 15% of total cars on the road. According to the figure the electric cars density by 2030 will also be 15%, i.e., four electric cars per 1000 people.

10.4 Assessment of Power Distribution Utilities

10.4.1 Country Macros and Policy Frameworks Guiding Utilities' Overall Performance

In newly-independent Pakistan, the entire electricity infrastructure was in the hands of the public sector. However, in the early 90s, following the global drive towards unbundling the power sector, reforms were introduced to ensure performance. The Strategic Plan for Restructuring the Pakistan Power Sector was introduced. Under these reforms, the power sector was split into various entities, with Water and Power Development Authority (WAPDA) only responsible for hydro power. Generation companies (GENCOs) and independent power producers (IPPs) were responsible, along with WAPDA, for power generation. National Transmission and Dispatch Company (NTDC) was created to oversee transmission. The National Power Control Centre (NPCC) was to manage voltage and frequency control of the transmission grid and to match demand with supply. On the distribution side, 10 distribution companies (DISCOs) were created to distribute power to consumers. A separate independent body, National Electricity and Power Regulatory Authority (NEPRA)[27] was formed to oversee fairness among various stakeholders. Central Power Purchase Agency (CPPA) was made responsible for the purchase of wholesale power and its sale to distribution companies. It is to be noted that apart from the IPPs, all the entities involved are state owned. K-Electric is the only privately-owned vertically integrated utility in Pakistan with its own mandate. It generates its own power and also purchases power from CPPA like other utilities. A few years back, another DISCO was split and now Pakistan has 11 DISCOs in total.

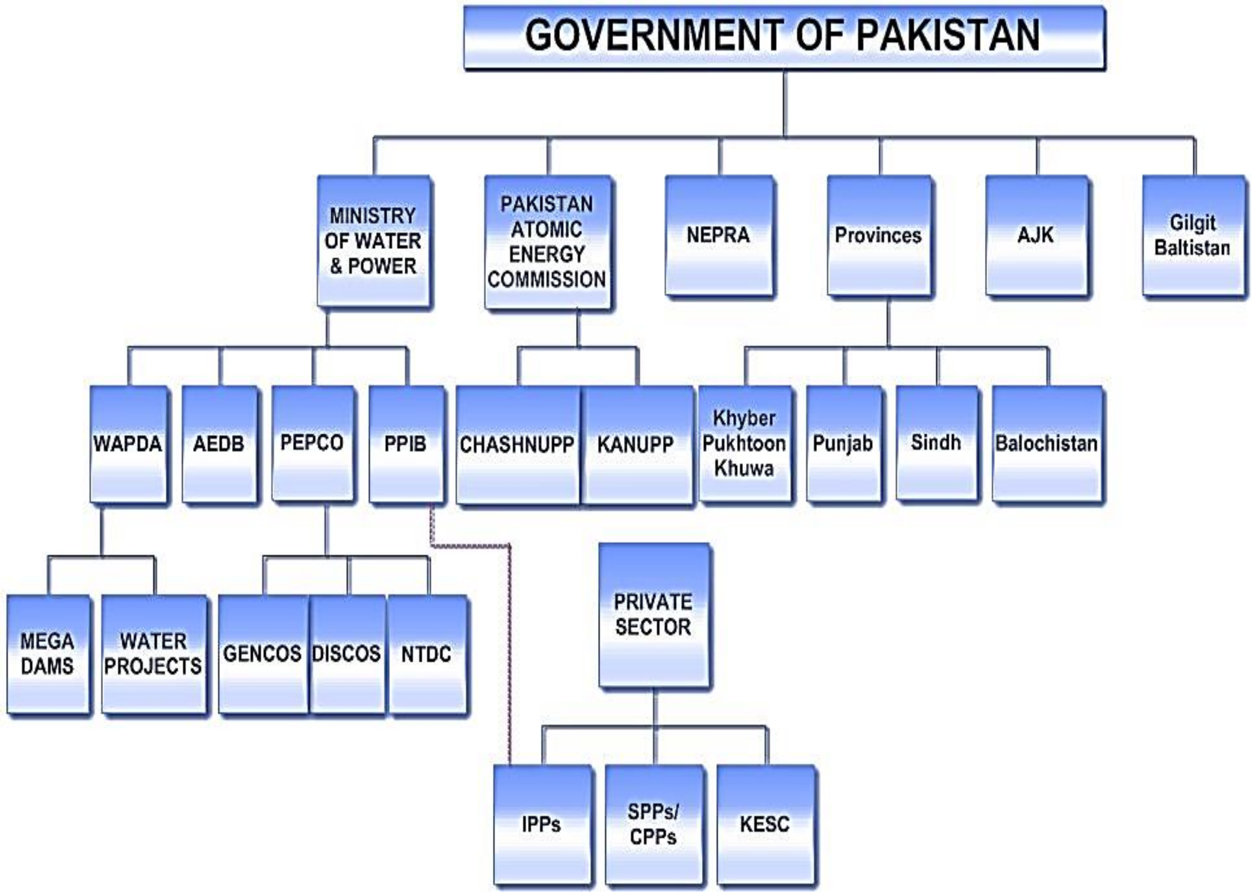
In order to purchase electricity, the DISCOs communicate their demands to NTDC. The NPCC allots power to the DISCOs from various generation sources according to an economic merit order on a daily basis. The economic merit order lists the available generation sources according to their costs. The cheapest sources are utilised first and transactions are made through the CPPA. The generation companies are paid according to the electricity they supply. Besides that, in order to provide them with incentives to invest, they are guaranteed capacity payments even if they don't supply any electricity.

In the late 2000s and early 2010s Pakistan suffered a major electricity shortage. As a result, long hours of

[27] NEPRA, State of Industry Report 2018 https://www.nepra.org.pk

load shedding were experienced even in major cities of the country. In order to overcome the problem, a large number of power plants were commissioned. This led to overcompensation, such that Pakistan now faces an electricity supply glut for the next several years. Already, the installed capacity of 33,000MW in 2018 was more than the demand which varied from 8,000 to 26,000MW during the year. By 2025, the peak generation capacity will be ~62,000 MW while demand might touch 34,000MW[28].

Figure 33: Organogram of Pakistan's Power Sector

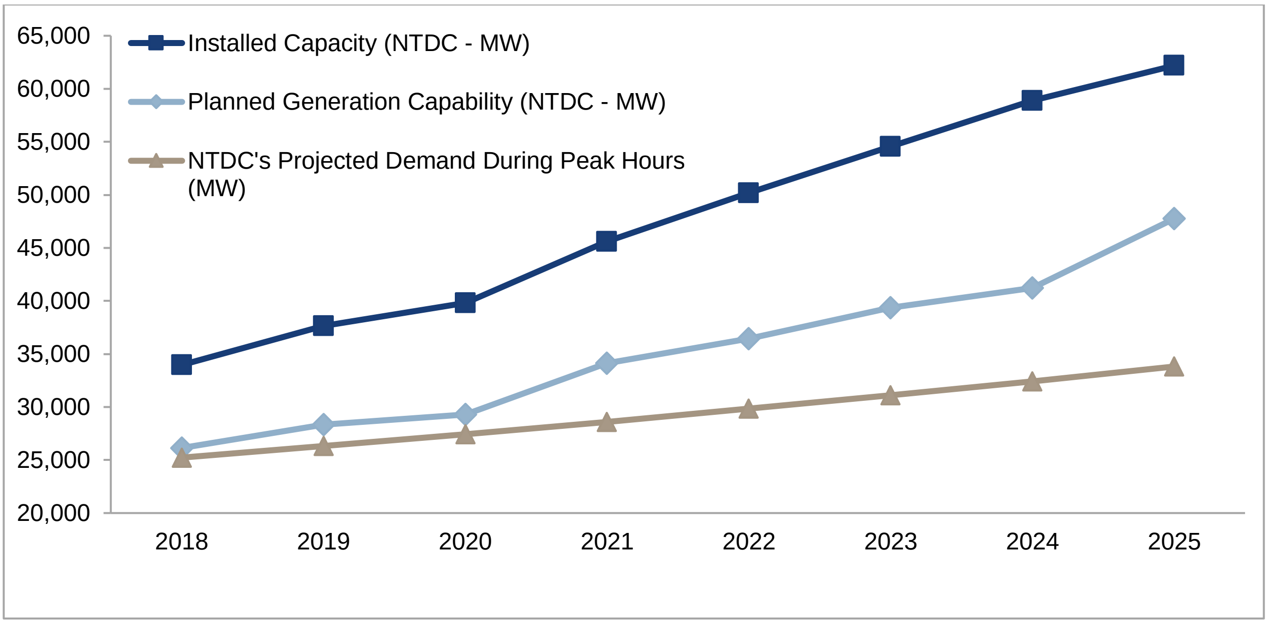


Source: Ministry of Energy (Power Division)

The data about generation capability and future demand, as reported by NTDC, is shown in the following table. It may be noted that sufficient generation capability would be available in the NTDC system to meet future demand at peak times, representing a power surplus scenario.

[28] National Transmission & Dispatch Co. (NTDC)

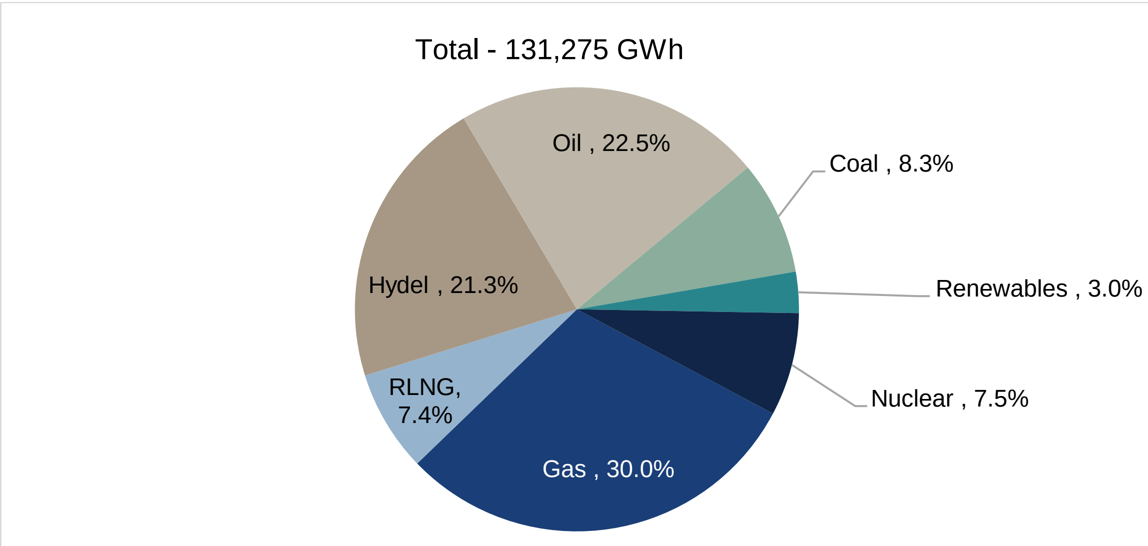
Figure 34: Power Demand Supply Projections of Pakistan



Source: NTDC, Power System Statistics 2019

The above graph shows an increase of 9% in annual generation capacity addition. Future additions will be based more on renewable energy and thermal (gas) power plants. NTDC has also planned transmission expansion according to capacity additions. These capacity additions don't include the distributed generation (roof-top solar, micro-hydro, etc.) It is projected that roof-top solar alone will reach 5 GW by 2025. Distributed generation is gaining pace, but DISCOs have expressed concern over greater power availability than that planned/purchased from CPPA.

Figure 35: Electricity Generation by Type (2017-18)



Source: Ministry of Energy (Petroleum Division), HDIP

10.4.2 Benchmarking of Utilities

The same benchmarking model, as applied on India has been replicated in case of Pakistan as well.

Readiness of Utilities to Set Up EV Charging Stations

The unbundling of WAPDA through power sector reforms resulted in creation of ten (10) DISCOs owned by the federal government. Currently, assets of 132 kV transmission networks and 11 kV and below distribution networks are allocated to DISCOs, which include 25,068 km of 132 kV transmission lines; 760 (seven hundred sixty) 132 kV Grid Stations that consist of 1,828 power transformers having transformation capacity of 45,324 MVA; 8,454 11 kV feeders; 323,961 km of 11 kV lines; 681,805 distribution transformers having transformation capacity of 43,295 MVA and 232,042 km of LT lines. In addition to above, K - Electric is a vertically-integrated company having a distribution license granted by NEPRA. K – Electric is responsible for 338 km of 220 kV transmission lines, 8 (eight) 220 kV grid stations with transformation capacity of 3,080 MVA, 766 km of 132 kV transmission lines, 63 (sixty three) 132 kV grid stations having transformation capacity of 5,648 MVA, 1,653 11 kV Feeders, 9,363 Km of 11 kV lines, 25,667 distribution transformers having 7,230 MVA and 19,962 km of LT lines[29].

The T&D losses of DISCOs are among the most discussed and debated issues in the context of the power sector. The Regulator (NEPRA) has also been advising and directing the DISCOs to take operational and managerial steps to rein in their losses to more prudent levels. NEPRA has also allowed huge fund investments every year into DISCOs so that new and critical projects are initiated and completed on time. Since all DISCOs are owned and controlled by the Ministry of Energy (Power Division), the Regulator has been pointing out this critical issue to relevant quarters at all fora. The table below shows the operational parameters of DISCOs' performance for fiscal 2018[30].

Table 80: Operational Performance Indicators of DISCO's in Pakistan

Operational Metrics	AT&C Losses (%)	Distribution Losses (%)	Collection Efficiency (%)	Billing Efficiency (%)
IESCO	9.0	7.3	91.9	92.9
GEPCO	10.2	8.9	96.0	91.3
FESCO	10.6	8.8	97.2	91.3
TESCO	15.4	12.3	82.9	87.7
MEPCO	16.9	14.6	96.2	85.8
LESCO	22.7	12.8	92.9	86.2
QESCO	23.1	21.5	43.6	78.9

[29] K - Electric Annual Report 2017-18

[30] DISCO's; NEPRA Tariff Petitions 2017-18

Operational Metrics	AT&C Losses (%)	Distribution Losses (%)	Collection Efficiency (%)	Billing Efficiency (%)
K - Electric	25.2	20.5	90.0	76.3
PESCO	32.6	30.5	89.29	70.5
SEPCO	37.9	35.3	110.0	65.4
HESCO	41.8	38.0	93.7	62.0

Note: IESCO: Islamabad Electric Supply Company, GEPCO: Gujranwala Electric Power Company, FESCO: Faisalabad Electric Supply Company, TESCO: Tribal Electric Supply Company, MEPCO: Multan Electric Power Company, LESCO: Lahore Electric Supply Company, QESCO: Quetta Electric Supply Company, KEL: K-Electric, PESCO: Peshawar Electric Power Company, SEPCO: Sukkur Electric Power Company, HESCO: Hyderabad Electric Supply Company

Source: NEPRA, All Distribution Companies

It may be noted that as a whole, DISCOs have not shown any improvement in reduction of transmission and distribution losses for fiscal 2018. IESCO, GEPCO and FESCO are the three top-performing DISCOs in terms of the least distribution losses. Losses of MEPCO and LESCO increased as compared with previous years; however, it is a matter of concern that one of the better DISCOs i.e., LESCO could not reduce or even maintain its losses at the fiscal 2017 level. The losses in HESCO, SEPCO and PESCO are very high as compared with the allowed limits by NEPRA. However, PESCO has shown improvement in reduction of distribution losses. DISCOs need to improve their operational performance to take advantage of the improved electricity supply availability; otherwise the financial position of the power sector and the overall economy will have a huge negative impact.

To narrow down the areas of interest, the above table shows performance of all the DISCOs in the four major categories of consumers. It may be noted that FESCO, MEPCO and GEPCO were able to maintain quite consistent and satisfactory collection efficiencies for all the consumer categories. HESCO, LESCO, KEL and IESCO also showed reasonable collection efficiencies, but have shown improvements as compared with previous years. IESCO's recovery is a bit low as compared with the top performing DISCOs because of the balance payments of federal government ministries. LESCO needs to focus more on agricultural consumers to improve its recovery position for this category. PESCO has shown an overall improvement in this area; however, its recovery in domestic category is close to 84%, requiring sustained efforts by the company management to target above 90% recovery in this category. It is observed that HESCO and SEPCO require effort to improve their recovery position in the domestic sector. QESCO's inferior performance is mainly due to poor recovery position of agricultural and domestic consumers.

Overloading in DISCO System

Power delivery through DISCOs' networks mainly depends on the adequacy of three major components, including power transformers (mostly 132/11 kV transformers), 11 kV feeders and finally, the distribution transformers. The following tables provide a comparison of overloaded components in all DISCOs for fiscal 2017. Overloading of these three components show the stability of the distribution system of DISCOs.

Power transformers: On an overall country basis, overloading on power transformers has slightly reduced in fiscal 2017 but is still very high as 38% of the total power transformers in the DISCOs are overloaded, pointing to potential problems. On a DISCO to DISCO comparison, FESCO and QESCO have more than their 50% power transformers overloaded above 80%, followed by HESCO, PESCO and SEPCO having more than 40% of their transformers overloaded. IESCO has the lowest percentage of overloading of power transformers[31].

Table 81: Performance of Power Transformers of DISCO's in Pakistan

Name of DISCO	Total No of Power Transformers	Total No of Overloaded Power Transformers (Above 80%)	Percentage of Total Overloaded Power Transformers (Above 80%)
QESCO	133	75	56.40%
FESCO	195	100	51.30%
HESCO	119	59	49.60%
PESCO	230	113	49.10%
SEPCO	118	53	44.90%
LESCO	351	127	36.20%
TESCO	38	13	34.20%
MEPCO	282	75	26.60%
GEPCO	160	34	21.30%
IESCO	202	24	11.90%

**Power Transformers Include 132kV, 66kV and 33kV Voltage Level*
Source: NEPRA, All Distribution Companies

11 KV Feeders: Overloading on 11 kV feeders has increased, as 34% of the total feeders are loaded above 80% compared to 28.14% last year. On the DISCO level, PESCO and TESCO have the highest percentage (more than 50%) of overloaded feeders, followed by QESCO, SEPCO, MEPCO and LESCO (more than 30%). IESCO, GEPCO and FESCO has the lowest percentage of overloaded feeders[32].

Table 82: Over Loaded 11kV Feeders of DISCO's in Pakistan

Name of DISCO	Total No. of 11kV Feeders	Total No. of Over Loaded 11kV Feeders (Above 80%)	Percentage of Total Over Loaded 11kV Feeders (Above 80%)
TESCO	203	191	94.10%

[31] State of Industry Report 2017-18, NEPRA
[32] DISCO's Performance Report 2017-18, NEPRA

Name of DISCO	Total No. of 11kV Feeders	Total No. of Over Loaded 11kV Feeders (Above 80%)	Percentage of Total Over Loaded 11kV Feeders (Above 80%)
PESCO	946	485	51.30%
QESCO	628	233	37.10%
SEPCO	462	167	36.10%
MEPCO	1241	433	34.90%
LESCO	1650	548	33.20%
HESCO	463	121	26.10%
FESCO	998	159	15.90%
GEPCO	805	88	10.90%
IESCO	1058	27	2.60%

Source: NEPRA, All Distribution Companies

Distribution Transformers: Overloading of distribution transformers in case of LESCO at 30.13% is the highest among DISCOs, followed by PESCO and SEPCO[33]. Rest of the DISCOs have performed better.

Table 83: Over Loaded Distribution Transformers of DISCO's in Pakistan

Name of DISCO	No. of Distribution Transformers	No. of Over Loaded Distribution Transformers (Above 80%)	Percentage of Total Over Loaded Distribution Transformers (Above 80%)
LESCO	100,718	30,350	30.10%
PESCO	72,078	21,033	29.20%
SEPCO	35,875	7,424	20.70%
QESCO	55,770	8,873	15.90%
HESCO	35,996	3,340	9.30%
IESCO	46,359	2,868	6.20%
MEPCO	156,460	8,128	5.20%
GEPCO	61,661	1,475	2.40%
FESCO	100,276	1,843	1.80%
TESCO	16,612	191	1.10%

Source: NEPRA, All Distribution Companies

From above it is noted that although PESCO, SEPCO, TESCO and QESCO have generally been accepted as those DISCOs, which have consistently shown poor performance levels, what is more worrying however, is that according to the above statistics, the so called better performers like LESCO and MEPCO have a poor record for 11 kV overloaded feeders. LESCO has the worst record of overloading of distribution

[33] DISCO's Performance Report 2017-18, NEPRA

transformers. Similarly, FESCO has very serious issues to tackle with the overloading of its power transformers. Considering the share of these DISCOs in the overall energy consumption, further delays in overcoming these issues will be disastrous for the power sector. KEL's failure to add adequate number of power transformers was among the major reasons for frequent tripping and prolonged load-shed hours.

LESCO, KEL and FESCO have highest industrial and commercial consumer penetration, which supports financial stability and future expansion. IESCO is the only DISCO having the highest number of domestic consumers and the highest recovery rate from them. Rest of the DISCO' have fairly low industrial and commercial consumer penetration. These figures may change in coming years, as new industrial clusters are announced under China Pakistan Economic Corridor (CPEC). NEPRA has emphasized on all forums to enhance the capability of DISCOs for self-sustainable business models, but due to inefficiencies and low collection ratios the DISCOs are contributing to the increase of circular debt. In the annual tariff petition by DISCOs, CAPEX is set for expansion of network as well as to enhance the efficiencies of the system, still few DISCOs are unable to meet the standards set by NEPRA.

10.4.3 Shortlisted Utility

The following DISCOs have been identified from Pakistan (based on the top three final rankings):

Name of DISCO	Area of Operation
Islamabad Electric Supply Company (IESCO)	Islamabad region
Faisalabad Electric Supply Company (FESCO)	Faisalabad region
Gujranwala Electric Power Company (GEPCO)	Gujranwala region, Punjab

Based on the interest evinced by the shortlisted utilities and the intention to mutually work on the project, Islamabad Electric Supply Company (IESCO) was finalised for further research.

10.5 Planning for the Transition

10.5.1 Charging Standards and Charger Type

Poor range and higher capital costs have long been the two biggest bottlenecks to EV uptake. Now, however, every auto manufacturer is launching EV models to debut by 2025, with ranges that progressively top 300-plus kilometre (200 miles). These attributes pose less of a hurdle in gaining global traction. If consumers purchase EVs at the expected rates in the next five to ten years, a lack of charging infrastructure could become an obstacle to EV adoption. Assuming Pakistan's scenario, the lack of charging infrastructure may not be a hurdle even until 2030.

Along with different levels of EV adoption across the country, structural considerations will make charging-station demand highly localised. Combined home, work, and long-distance charging could in theory cover an EV owner's entire energy demand. For instance, drivers without chargers at home or work, drivers who exceed their battery range, and drivers who forget to charge at home or don't have home chargers must rely on other options such as public charging and making the situation for public charging. Initially a mix of fast and medium chargers will make more economical sense, and as time passes with the increase in number of EVs, the density of charging infrastructure may be upgraded according to growth.

Different countries/regions follow different charger configurations according to their charging capabilities. The kilowatt capacity of a charger defines the rate at which the battery will be charged, and it also defines that at which place such chargers can be deployed.

It is difficult to analyse the uptake of EVs in the new markets for the type of charger to be used in the future. For the purpose of analysis, the type of chargers is generalised and distributed in three categories, i.e., slow chargers, semi-fast chargers, and fast chargers. For the Pakistan market, a detailed deployment plan has been chalked out in the section of potential charging locations, showing what type of chargers will be deployed in different locations.

Charging Stations Suitable for Pakistan

Plug-in hybrids are more popular than full-electric cars, as there is a lack of awareness for adoption in the market. People are a bit reluctant in taking the risk and higher capital costs are also a factor of slow take-off. Pakistan's auto sector is highly influenced by Japanese auto manufacturers, but after the Auto Policy 2016, new entrants are coming in that will change the market shares. Looking at the used-car statistics, almost 90% of the used hybrid cars were imported from Japan last year. For plug-in hybrids and full-electric cars, the trends cannot be gauged as the number total number of cars is very less. Till date only handful of plug-in hybrid and full-electric cars are registered in Pakistan. Assuming the pace of adoption of hybrid cars, analysing the available data of previous 5 years, we can assume that the plug-in hybrids will gain traction in the coming years, followed by the transition to full-electric cars. Pakistan's market will be dependent on the import of plug-in hybrids and battery electric vehicles in coming years, but according to the signed MoUs with BYD, China and Hyundai, they will start assembly lines in Pakistan, which will change the dynamics of EV adoption in Pakistan.

Two and three-wheeler electric vehicles in Pakistan are not in the picture yet, but in future two-wheelers may get more traction. The two- and three-wheeler segments use low-voltage slow-charging technology. So, it is likely that they will be charged at homes or work places. For busses and other segments, public charging stations are technically not viable.

For electric cars, there are multiple auto manufacturers with different charging configurations. Pakistan's public charging infrastructure will be driven by the players with large market share in future. For the initial five years, there will be a combination of different charging options. Probably medium or semi-fast chargers will dominate the charging infrastructure with CHAdeMO or CCS. As the density of EVs increase, the next phase will require the installation of fast chargers for electric car owners with higher power ratings. The suggestion to go with the most popular charging technologies, which are likely most widely available, will be an intelligent choice. Hyundai recently launched the first electric car IONIQ in Pakistan, which uses CHAdeMO technology. Toyota is marketing its JDM model of Prius Prime (a plug-in hybrid) in Pakistan with CHAdeMO technology. New entrants have models that support the CCS technology. This makes the case for both CHAdeMO and CCS technology viable options for Pakistan. Additionally, public-charging infrastructure will be a combination of both widely used technologies.

Another avenue may be to develop own charging standards for Pakistan. But this option only favors those countries that either have good EV penetration or expect large EV penetration in the near future.

10.5.2 Grid Augmentation

The expected rise of electric vehicles will lead to significant additional demand on low-voltage (LV) distribution systems. Uncontrolled charging could lead to problems, such as thermal overload of transformers and lines, voltage fluctuation, harmonics, and phase unbalance. The utilities will have to respond to these challenges upfront and plan the strategies to combat accordingly.

Power Requirement for EV Charging Stations

Due to rapid urbanization, the possibility of land squeeze will be much greater than expected. Today's power facilities can accommodate tomorrow's significant rise in the number of EVs, as long as the vehicles are charged off peak. Faster charging during peak demand, however, will indeed have an impact on the power system.

Most of the present distribution networks in Pakistan are quite old, making them quite unequipped to withstand the large-scale integration. The electric vehicles are non-linear loads, which cause harmonic distortions and voltage stability issues.

In Pakistan, distribution companies have CAPEX planned for activities, such as maintenance and grid expansion. For non-linear loads of electric vehicles, electric utilities or the regulatory authority will have to develop the grid codes for EV charging. More improvements for the system upgrades will also be required to support large scale EV charging infrastructure deployment.

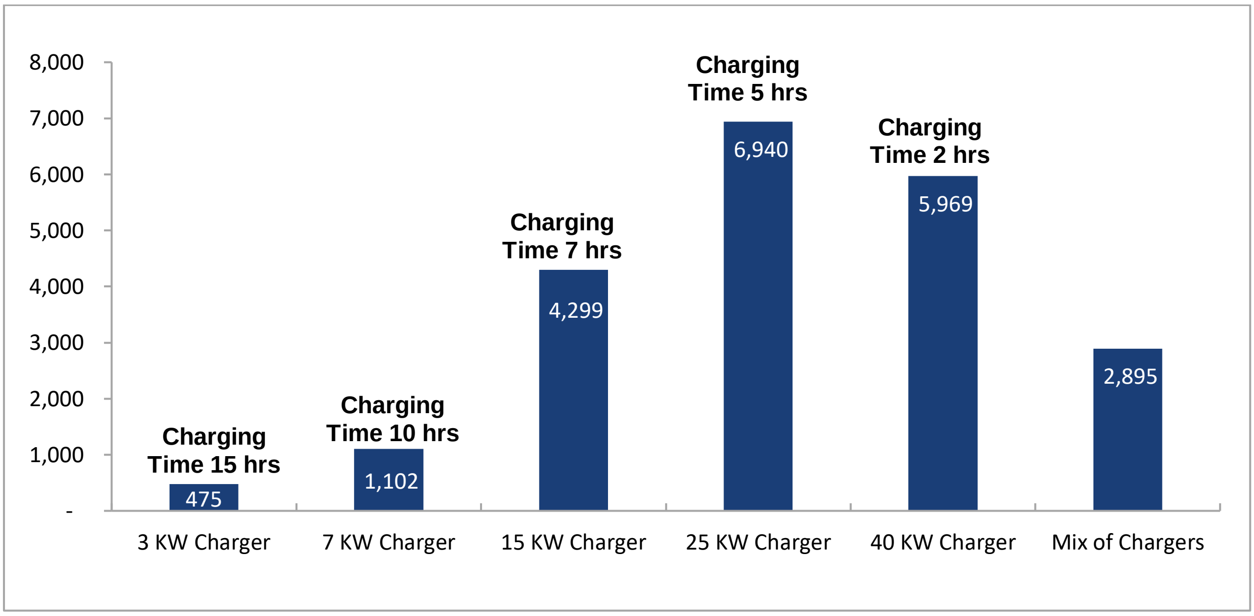
The energy consumed at home and in the workplace will depend on the number of chargers installed and the amount of energy those chargers provide. Home charging will depend on whether EV owners have garages and on their income demographics. Charger penetration at work will predominantly reflect employer choice or regulatory requirements. Initially, as the EV sales start, it is unlikely that it can cause a significant increase in total power demand, it is likely that it will reshape the electricity load curve. The most pronounced effect will be an increase in evening peak loads, as people plug in their EVs when they return home from work or other activities.

To get an insight of the power requirement increase due to EV charging infrastructure integration, a simulation has been run on a simulator developed by Energy Informative Group, LUMS. The following parameters are required by the simulator for analysis:

- Number of EV to be charged
- Analysis period
- Hours taken by vehicle to charge (hours)
- Charger peak power capacity (kW)
- Transmission and charger losses (%)

At the backend of the simulator, all the database of National Transmission and Dispatch Company is synchronised. On the basis of accurate data, the analysis is done. The simulator also has the flexibility to change the peak and off-peak charging hours. Apart from these indicators, other considerations are also built in the simulator to analyse the grid load profile due to EV integration.

Figure 36: Simulation Results from Impact of EV Charging



Source: LUMS, Energy Informatics Group, EV Simulator

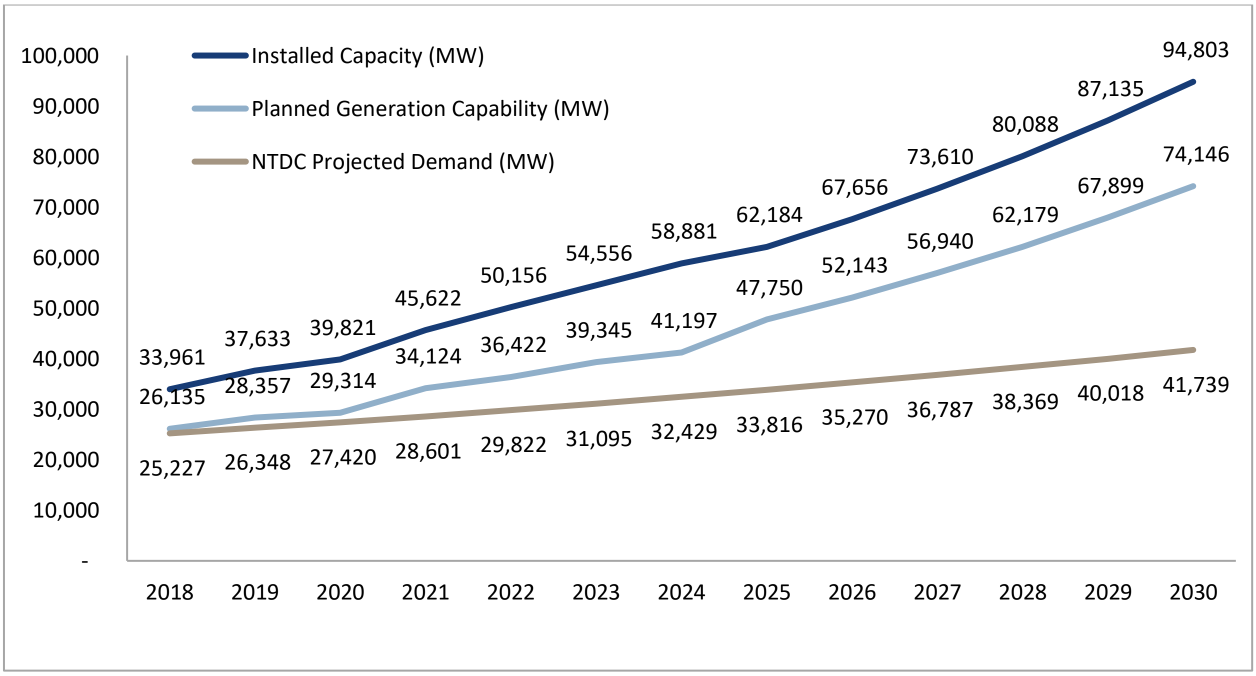
For the analysis, we have considered a maximum of 1 million EVs charged. The above figure shows the peak demand created due to each type of charger used throughout the year. The charging time required by EV charger is also mentioned. As one may notice the uncertainty in the hours required to charge an EV is because the charger may have the extra power capacity to charge, but the acceptance power rate of the vehicle may not support that. But in future we expect to have higher power acceptance rates of EVs, which are at par with the high charging power capacities of fast chargers.

The EV charger deployment is not restricted to a single charger type or capacity, practically the EV charger deployment is a mix of charger types according to site requirements and EV penetration in the area or the capacity utilisation of the charging station. Considering the realism, a mix of charger types is considered with different deployment ratios. Maximum weightage is given to semi-fast and slow chargers, and only 5% weightage is given to fast chargers to calculate the maximum peak power demand required by the EV chargers.

Impact of Grid for High-Scale Adoption

It is very unlikely that electric vehicles will create a power demand crisis in Pakistan, but could reshape the load curve over years. Of late, strong power-sector reforms are working well and CPEC support to the power sector is also helping the sector to stabilize and grow well. As show in the graph below, by 2030 Pakistan will have significant margin in power generation and power demand. This energy gap is expected to widen in the upcoming years, as new power plants are planned for interconnection to the grid. So, it is evident that if we have about 1 million EVs on roads, still we would have ample extra power available to charge all EVs by 2030.

Figure 37: Power System Forecast of Pakistan

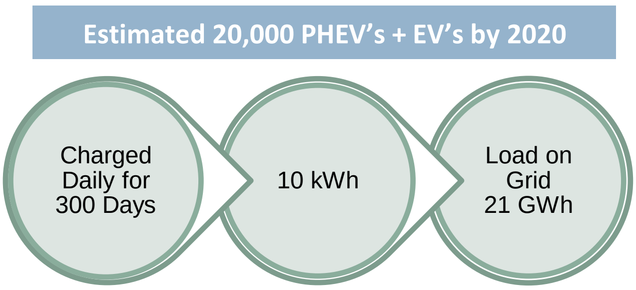


Source: NTDC, Power System Statistics 2019

For the estimated load on the grid for charging these EVs, we have shown three estimates for increase in energy use over years, i.e., by 2020, 2025 and 2030.

As per the available data and based on estimates, we have assumed that each PHEV, 2 & 3 - wheelers will roughly require 10 kWh of energy per day. The reason for taking 10 kWh benchmark to charge each vehicle is that, initially we expect high penetration of PHEVs, 2 and 3 - wheelers and over years this trend will shift towards pure EVs. The daily energy consumption for 20,000 EVs, by 2020, which will require about 21 GWh of energy to fully charge, after 18% transmission and distribution losses have been taken into account. While considering the energy requirements we have also considered that two- and three-wheelers will account for 10% and rest will be cars/jeeps.

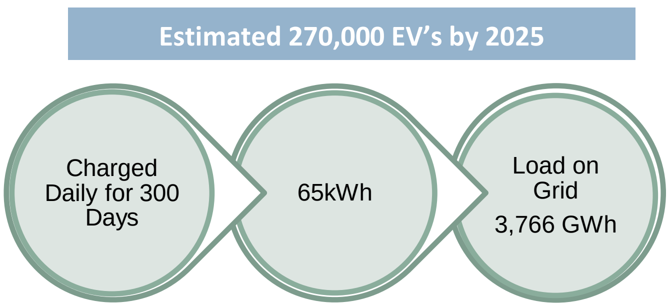
Figure 38: Energy Requirement Estimations for EV by 2020



Source: Estimations based on historical data of PAMA

As support policies evolve and new manufacturers come into the market, the next five years will a show progress of adoption of pure EVs and the ratio of plug-in hybrids is expected to decline. For the next five years, by 2025, the number of EVs is expected to grow to about 270,000 units. Considering the penetration of pure EVs will increase, we assume on an average 65 kWh will be required to fully charge each vehicle. The total energy required to fully charge these EVs will be about 3,766 GWh taking into account 18% transmission and distribution losses. Over years, as the battery life depletes, that loss will increase the frequency of charging, but that has not been incorporated while calculating the total energy requirement.

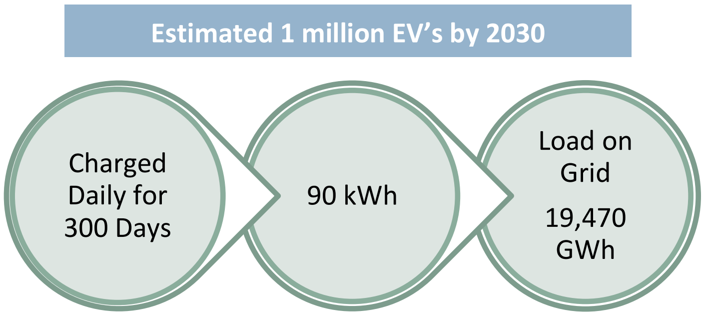
Figure 39: Energy Requirement Estimations for EV by 2025



Source: Estimations based on historical data of PAMA

Moving on with EVs getting traction in the market, it is likely that in the next five years phase, the total number of EVs will reach the milestone of 1 million EVs in 2030. As of now EVs have range (mileage) issues on a single charge, but with technology advancements, the battery sizes will increase, which would require more energy to charge the EVs. Considering that we assume on an average 90 kWh will be required to fully charge each vehicle, the total energy required to fully charge these EVs be about 19,470 GWh, taking into account 18% transmission and distribution losses. Over the years the battery life depletes, that loss will increase the frequency of charging, but that has not been incorporated while calculating the total energy requirement.

Figure 40: Energy Requirement Estimations for EVs by 2030



Source: Estimations based on historical data of PAMA

Remediation Strategies

Based on estimations for the energy required to charge EVs, the peak power demand may not be too much to handle in terms of power available. As shown in the figure titled "Power system forecast of Pakistan", there is ample difference between planned power generation and the expected load profile till 2030. In terms of power generation, the network can easily adapt to the increasing power demand owing to EV integration. However, utilities will have to respond to the increase in power demand and its impact on power quality, grid expansion, etc.

For increase in demand, the electric utilities will have to request the Central Power Purchasing Authority (CPPA) to increase their sanctioned load according to their demand. The utilities will have to run the demand side management drill incorporating the impact of EVs on their system. For the required technical upgrades, the following remedial measures may help utilities in future:

- Use of Flexible Alternating Current Transmission System (FACT) devices in the distribution system for improved power quality
- Upgradation of the distribution network, i.e., power transformers, cables, etc.
- Re-conductoring of distribution lines for stability of the system
- Upgradation of system software for planning and analysis
- Capacity building of staff/ technicians/engineers

10.5.3 Charging Locations

To promote accessibility for EV charging within all communities, stringent strategic mapping of locations to EV charging infrastructure is very important. The installation of EV infrastructure, if properly done, can encourage the uptake of EVs across Pakistan. This assessment of identifying the potential locations will help determine when and to what extent governments and private sector entities need to invest in charging infrastructure to enable EV adoption.

The financial investments associated with these choices are enormous. Thus, a paradigm shift in transportation and mobility thinking towards a low-carbon future requires the most optimal, strategic and efficient investments into EVs. This is a complex process to map potential locations, given the current lack of general EV adoption today. PHEVs / EVs still represent less than 1% of all new vehicle purchases in Pakistan.

One indicator while identifying potential areas will be the placement of the stations in locations that can result in the most efficient usage/utilisation. Other indicators include determining the number of charging stations, grid availability, required grid side investments, and communications standards.

Apart from the above indicators, one other factor also affects the process of identifying the quantity and placement of the EV infrastructure. Global studies have shown "early adopters" among EV owners are predominantly male, highly educated, and high-income earners. The problem is if the EV deployment strategy is solely based on areas within which "early adopters" reside or charge their vehicles, it will tend to favour the privileged sectors of society rather than society at large. So, it is important to keep all factors in view while developing a strategy for an unexplored market such as Pakistan. In early years, deploying public chargers that target the privileged sector may give an edge to EV usage. However, in the long term, the deployment plan should be to cover all areas under the jurisdiction of IESCO.

Distance Considerations in EVSE Placements

The purpose of this methodology is to fill gaps in the EV network. This will help place EV chargers at equi-distance from one another to ensure drivers have access to public chargers throughout the community and never find themselves too far away from a charging site. Long distances between chargers make longer-range driving infeasible.

EV Consumer Density Consideration

To determine optimal locations for fast charging, easily accessible sites needed to be located. The types of destinations shortlisted are supermarkets, department stores, shopping malls, restaurants, and short-term parking spots. After assessment, we determined the following places that would attract drivers to travel "medium-to-long" distances from their home and remain parked for at least one hour. This was deemed to be generally sufficient time to charge an EV using a public charger to complete a return trip home. This assessment included locations such as shopping malls, restaurants, amusement parks, parking lots, libraries, universities, and hospitals.

Based on all the assessments, indicators and local dynamics, the following criteria have been finalized for the selection of potential areas where public EV chargers can be deployed in the twin cities of Islamabad and Rawalpindi under IESCO, the power distribution company.

- Distance consideration (10 km radius)
- Efficient utilisation (minimum 20% utilisation)
- Land availability (at least three parking lots vacant for EV charging)
- Grid availability and excess power availability on the 11KV distribution feeder
- Required minimum investment for grid integration (associated costs)

EV Chargers Deployment Plan in IESCO Region

With detailed coordination with the IESCO planning team, the proposal is split in two phases. The first phase deals with locations having excess available power at the 11KV distribution level and locations which satisfy the above five indicators. In phase two, deployments will be undertaken to increase the density of the charging infrastructure. As EVs take off, the charging needs will most likely be satisfied with home charging. As time passes and EVs start getting traction, public charging requirements will increase. With the increase in demand, implementation of phase two will start. This topology will help reduce initial investments when the utilisation factor of each charging facility is less, and will make the investment more financially viable. The potential deployment will be done as a mix of slow and semi-fast chargers, according to the locations and their utilisation factors.

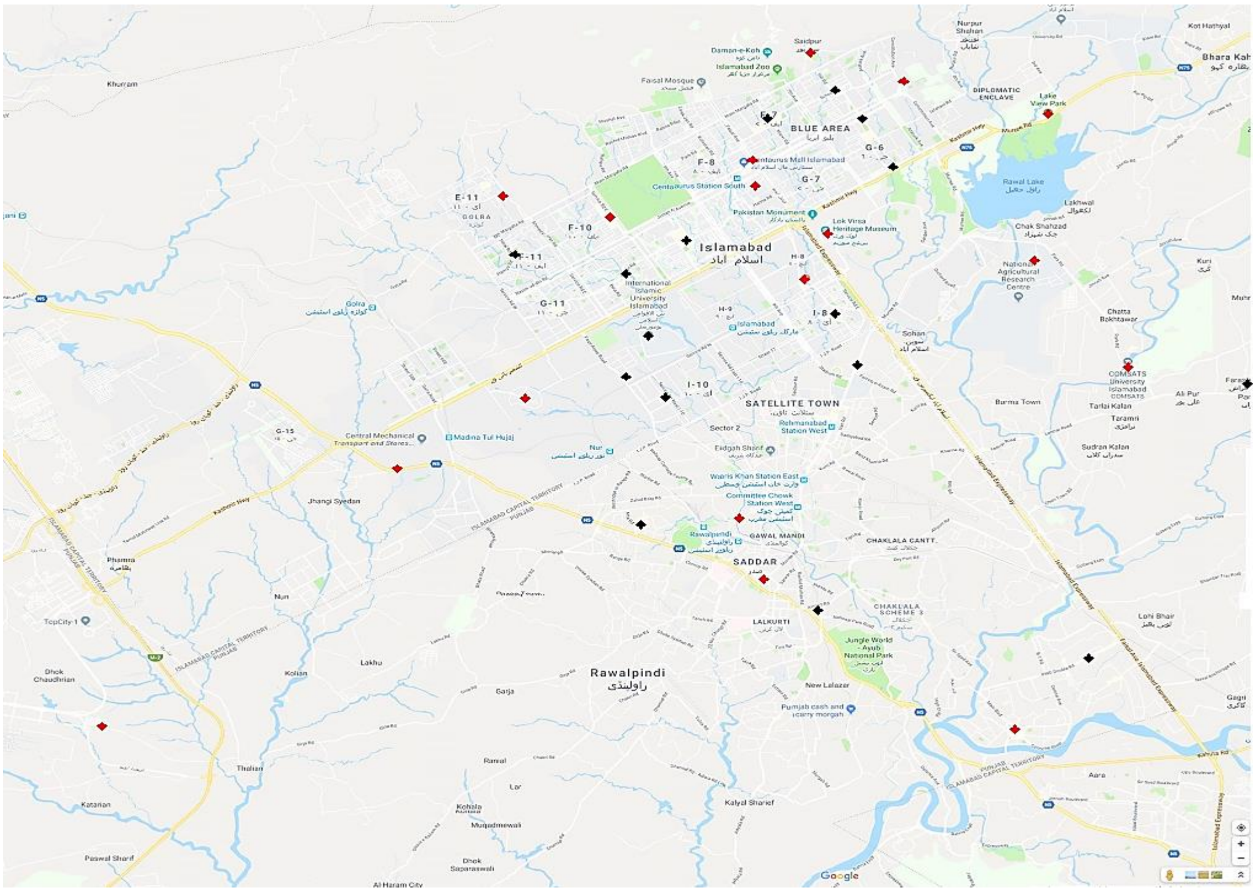
The analysis in shows IESCO is the top-performing utility. IESCO not only covers the urban area of the federal capital of Islamabad and Rawalpindi, but it also covers other circles and adjacent rural areas. While locating potential sites, only urban areas were considered as they would have a greater utilisation factor. In addition, the distribution infrastructure is also more stable to cater to the additional load on different nodes of potential sites.

For identifying the suitable locations, the installation recommendations are divided in two phases, i.e., phase 1 from 2020 to 2025 and phase 2 from 2025 to 2030. The main focus on location selection will be on urban centres to maximise the utilisation factor.

Phase 1 (2020-25)

This is the phase when the EV market is expected to take off. The number of vehicles will be very less initially, and would increase gradually. The increase may not be linear, as most of the vehicles will be imported. To promote public chargers among EV consumers, the stakeholders investing in charging infrastructure are recommended to have same protocols for identification of cars, billing systems, and service systems based upon open-source protocols. This will promote interoperability and allow all EV drivers to freely use all charging stations available. The potential sites identified for the first phase are shopping malls, parks, hospitals and restaurants, keeping in view the above-mentioned criteria for shortlisting.

Figure 41: Proposed Locations for Charging Stations in Rawalpindi-Islamabad Region



The picture above shows a complete map of the twin cities of Islamabad and Rawalpindi. The selected locations for phase 1 are marked in red and those for phase 2 are marked in black. Details of all potential locations, the category and proposed year of installation can be seen in table below.

Phase 2 (2026-30)

In the next phase, we expect the EV market to grow, creating demand for more public chargers. So, the next deployment plan will be focused on increasing the density of public EV chargers. Some deployments will be at new locations, decreasing the distance between available chargers, and some installations will be upgrading/increasing the charging ports at existing locations. The growth of EVs is based on the assumption of new EV manufacturers coming into Pakistan. According to their announced plans, they will be operational by 2022. By that time, the manufacturers will also start making efforts to establish their own charging networks to facilitate their own consumers. A detailed deployment plan, depicting the year-on-year deployment, is shown in the table below.

Table 84: Type of Charger in Potential Sites

Year	Sr No	Phase	Location Category	Potential Location	Slow Charger (max 15 kW)	Semi-Fast Charger (20-25 kW)	Fast Charger (>25 kW)
2020	1	Phase 1	Parking	Airport	2	1	
	2	Phase 1	Parking	Bahria Town Civic Center	1		
	3	Phase 1	Mall	Centaurus Mall	2	1	
	4	Phase 1	Parking	F- 9 Park (Mega Zone)	2		
	5	Phase 1	Parking	G-5 Government Offices	3		
	6	Phase 1	Mall	Jinnah Park	3		
	7	Phase 1	Parking	Murree Road - Metro Park & Ride	3	1	
	8	Phase 1	Parking	Saddar Parking Plaza	3	1	
	9	Phase 1	Hospital	Shifa International Hospital	2		
2021	10	Phase 1	Mall	Giga Mall RWP	2		
	11	Phase 1	Parking	Saidpur Cultural Village	2	1	
2022	12	Phase 1	Parking	Daewoo Terminal	2	1	
2023	13	Phase 1	Parking	DHA Main Market	1		
	14	phase 1	Parking	G-5 Government Offices	3		
2024	15	Phase 1	Parking	E-11 Markaz/ Marquees	2	0	
	16	Phase 1	Parking	Fawara Chowk Parking Plaza	2		
	17	Phase 1	Parking	Islamic University	1		
	18	Phase 1	Parking	Lake View Park	2	1	
	19	Phase 1	Parking	NUST University H-12	1		
2025	20	Phase 1	Parking	COMSATS University	1		
	21	Phase 1	Parking	NARC	2		
	22	Phase 1	Hospital	PIMS Hospital	2		
	23	Phase 1	Parking	Pir Sohawa/ Daman e Koh	2		
2026	24	Phase 2	Parking	Airport	2	1	
	25	Phase 2	Parking	Centaurus Mall	2		
	26	Phase 2	Hospital	Polyclinic Hospital	2		
	27	Phase 2	Parking	PWD Main Market	1		

Year	Sr No	Phase	Location Category	Potential Location	Slow Charger (max 15 kW)	Semi-Fast Charger (20-25 kW)	Fast Charger (>25 kW)
2027	28	Phase 2	Parking	F- 9 Park (Mega Zone)	2		
	29	Phase 2	Parking	Lok Virsa	1		
	30	Phase 2	Hospital	NESCOM Hospital	2		
	31	Phase 2	Parking	Saddar Parking Plaza	2	0	
2028	32	Phase 2	Parking	Daewoo Terminal	2		
	33	Phase 2	Parking	F -11 Markaz	2		
	34	Phase 2	Parking	Fast University	1		
	35	Phase 2	Parking	G-9 Markaz	1		
	36	Phase 2	Parking	I - 8 Markaz	1		
	37	Phase 2	Parking	Lake View Park	3		
	38	Phase 2	Parking	Metro Cash & Carry	1		
	39	Phase 2	Parking	Murree Road (Metro Park & Ride)	2		
2029	40	Phase 2	Parking	F-7 Markaz	2		
	41	Phase 2	Mall	Jinnah Park	1		
	42	Phase 2	Parking	PIEAS + Nilore	1		
2030	43	Phase 2	Parking	Abpara Market	1		
	44	Phase 2	Parking	F -6 Markaz	2		
	45	Phase 2	Parking	G-10 Markaz	1		
	46	Phase 2	Parking	Westridge	1		

Source: IESCO database of 11KV feeders, distribution transformers

10.5.4 CAPEX Requirement

Though a growing EV charging station infrastructure seems predictable, the EV ecosystem faces a financing dilemma. The installation of a public charging infrastructure on a large scale requires a significant amount of capital. It is not viable for the government or the utility to bear the cost alone. However, to minimize costs, consideration is given to a design that doesn't require more power than the available electrical capacity in the 11 KV feeder. If electrical upgrades are necessary, the costs can be minimized by placing the EV charging station close to the electrical service area. A long distance from the charging station to the electrical service can lead to higher auxiliary component costs such as wire and trenching.

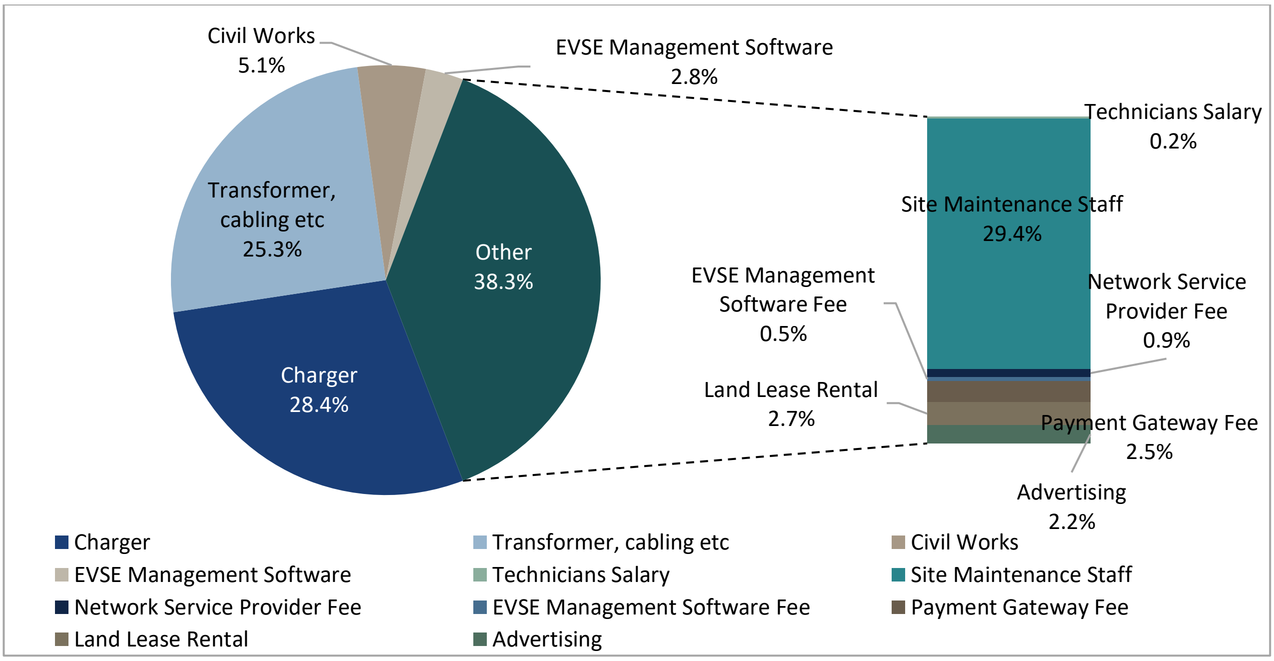
From the data provided by IESCO, it is observed from power transformers to the distribution system, IESCO has maintained its system well and system upgrades are timely. With an increase in power demand owing to EV charging, system upgrades may be required at substation levels. According to IESCO officials, they have already planned a CAPEX till 2030 for upgradation of the power system. The CAPEX is planned under three categories, i.e., Secondary Transmission & Grid (STG), Distribution System Rehabilitation (ELR), and Distribution System Expansion (DOP). The total CAPEX planned for these categories till 2030 is approximately 44,256 million PKR, and, if required, a separate budget can be requested for EV charging requirements. The officials were of the view that the implementation cannot only be done by IESCO; all stakeholders will have to play their role in rolling out EVs in Pakistan.

Setting up an EV charging station does not only include charger cost. Auxiliary component costs and operational expenses are also associated with it. The component cost covers the cost of EV charger, distribution transformer, cabling, electrical panel, energy meter, and the EVSE management software fee. The auxiliary cost covers the cost of installation and civil works. The ongoing expenses cover the cost of the network service provider fee, payment gateway fee, land lease rental, technicians, and site staff fee. The EVSE management software may be considered in two different ways of payment; either it can be an annual subscription fee or the software can be purchased as part of CAPEX. To minimize the operational cost, allocating the maintenance staff in clusters for two or three EV charging sites is considered.

The implementation plan for deployment of EV chargers is divided into two phases. The first phase reflects the creation of EV chargers' network in the twin cities. The next phase focuses on increasing the charger density in the potential areas.

For phase 1, CAPEX required by IESCO is approximately 55.4 million PKR and the operational expense is around 20.6 million PKR. For phase 2, the CAPEX required by IESCO is approximately 36.5 million PKR and the operational expense is around 36 million PKR. The detailed cost breakdown of the required capital and operation cost to run the EV charging stations are given in section below

Figure 42: Cost Breakdown of EV Charging Infrastructure



The figure above shows the CAPEX of the total project till 2030 is around 70% of the total cost; the rest is the operational cost. The major portion of the investment will be required for EV chargers and the auxiliary equipment to set up a charging station. The cost will be spent in phases according to the growth of demand for public EV chargers.

The cost of chargers varies with its peak charging capacity and on equipment supplier. The costs of different suppliers were assessed and while analysing an average cost has been taken into account. The average cost of a slow public charger (up to 20 kW) is assumed to be approximately 0.3 million PKR. The unit cost of a semi-fast charger (up to 25 kW) is assumed to be around 1 million PKR. For fast chargers, the capacity goes up to 100 kW, but it may not be feasible to deploy such oversized chargers for a new market. So, we assume a maximum 40 kW fast charger can be deployed in future if required. But, according to the charging acceptance rate of EVs, the charging power acceptance rate fluctuates between 7 kW to 15 kW across the mass-producing EVs.

The other major cost in setting up a charging station is the cost of the distribution transformer. The proposed distribution transformers for supporting the EV chargers are in the range of 25 kVA to 200 kVA according to the requirement of the location. It is an obligation on the commercial consumer by the utility to have a separate distribution transformer for a commercial activity. Few proposed sites have oversized distribution transformers to cater to new chargers according to future growth. The cost varies from 0.1 million to 1 million PKR for a 25 to 200 kVA distribution transformer. Usually, for the distribution system expansion, the electric utility provides the distribution transformer. However, in the case of commercial activity, the business entity will have to bear the cost of the required transformer.

The installation cost, cabling, trenching, and civil works cost varies according to each site. The costs depend upon the location, distance from electric service area, etc. Therefore, the costs are based on assumptions that all sites are within 40 meters of the electric service area. Civil works are also dependent on each individual site. For example, installation cost in a parking lot may also require a re-pavement cost. Installing a multiport station or multiple stations reduces the cost per charger, but the demand must exist to justify the extra capacity.

The other important cost is to have advanced EV management software which is capable of identifying a consumer, and has an online billing system and server communication. The cost of software can be a lump sum amount for the purchase of chargers from same supplier or it can have a monthly subscription-based model. For Pakistan, we have assumed 10% of net margin to be considered as a monthly EV management software fee.

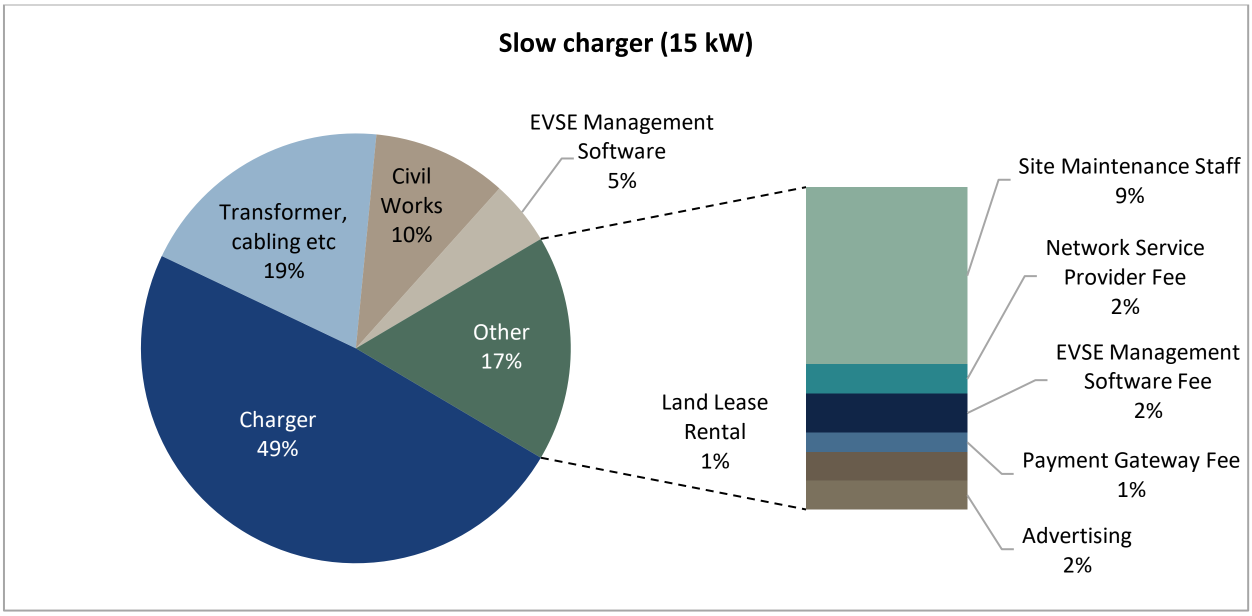
10.5.5 Financial Viability of Charging Stations

The economics of setting up a charging station is the deciding factor to take it to the level of implementation. Several economic indicators are involved while checking the financial viability of the project. In case of setting up charging stations in the twin cities, the analysis is based on the historical data forecast for the future growth of EVs. To analyse and get a better understanding of each charger category, we have done a separate analysis for realistic modelling. Few assumptions have been derived to minimize the annual operational cost of the charger. A single individual as site maintenance staff can handle three chargers at one site. The network provider fee remains fixed even if a maximum of three chargers are installed at one site.

Slow Chargers (Max 15 kW)

To deploy a slow public charger, the cost breakdown is shown in figure below. To analyse the economic viability, the capital cost and operational costs are expressed separately.

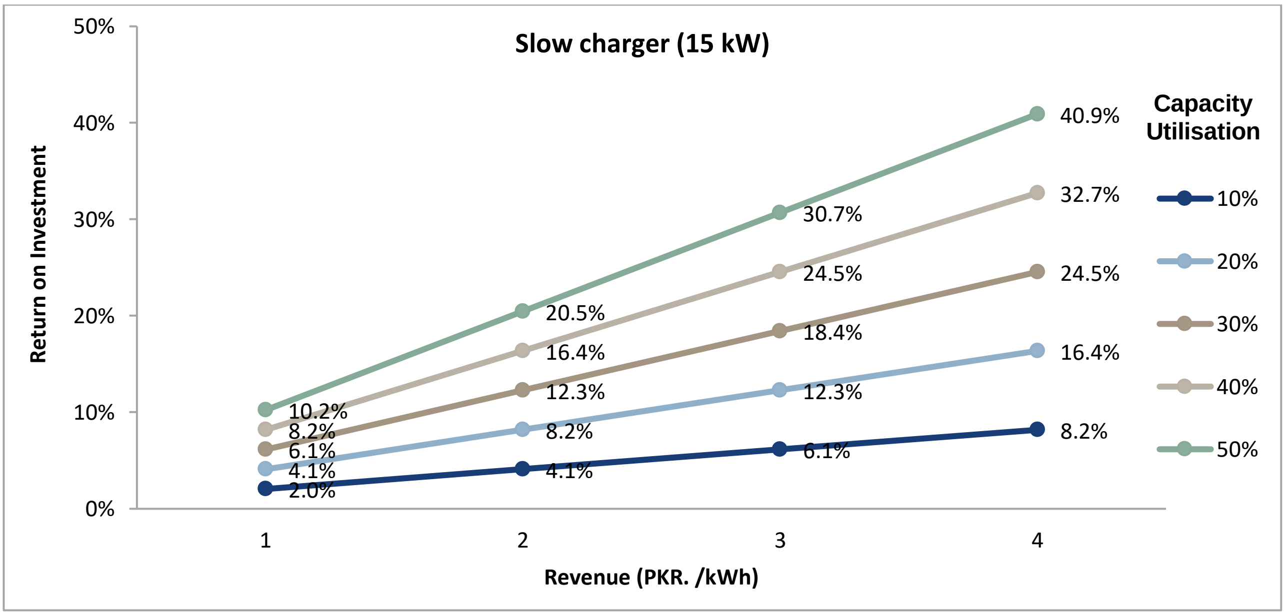
Figure 43: Cost Breakdown of the EV Charging Infrastructure – Slow Charger



As shown in the above figure, the CAPEX constitutes 83% and first-year operational cost constitutes for ~17%. With such a high CAPEX, most of the cost is for the equipment. With government support in terms of subsidies and tax incentives, the costs can be reduced to promote the use of public chargers in the initial years.

To get a financial insight, the utilisation factor of each charger is the major indicator to make it financially viable. The graph below shows the return on investment at different utilisation factors.

Figure 44: Return on Investment vs Capacity Utilisation Factor – Slow Charger

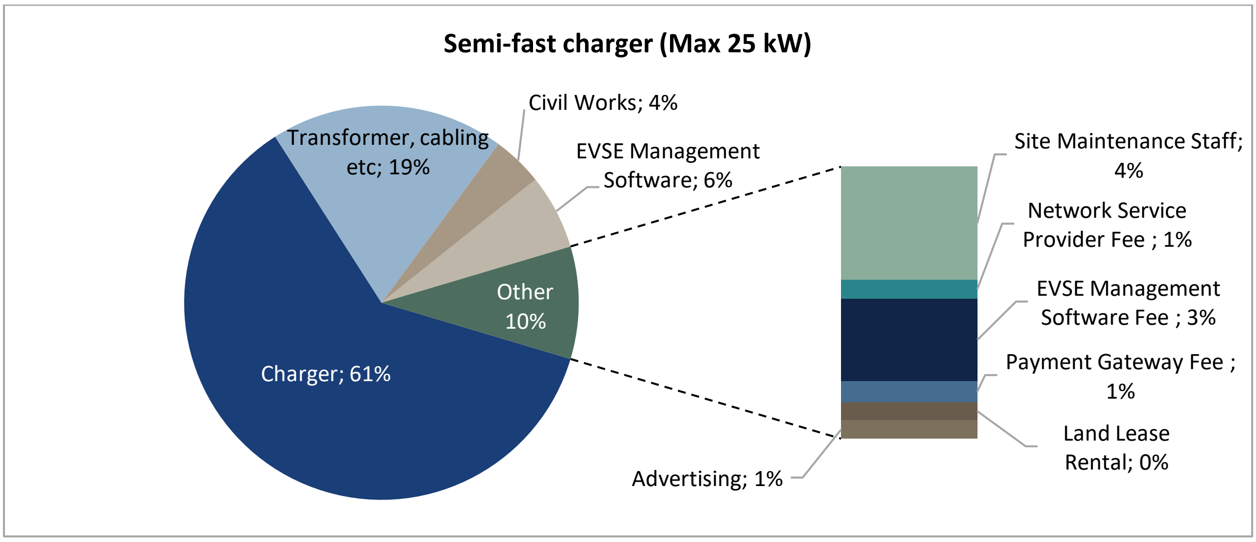


The analysis shows the annual return on investment can be higher at higher revenue (PKR/kWh), i.e., 4 PKR/kWh. However, at such higher charging costs, the EV consumers may be discouraged to use public chargers. So, a balance will have to be established between the return on investment according to the expected utilisation factors. In general, it is expected the utilisation factor in the initial years can be 10-20%. However, as the EVs gain traction, the average utilisation factor can be ~30%. As seen in the analysis, for 30% utilisation factor, the revenue per kWh can be PKR 2-3 and the return on investment can be 12-18%. For technology-oriented projects globally, the return on investment is 15-20%. This supports the case of slow public chargers being financially viable for investment. If the government can offer specialized tariff for EVs, then both the consumer and investor can benefit, promoting the adoption of EVs in Pakistan. Comparing this business model with the renewable energy projects in Pakistan, few projects were committed a return on investment of 17%. Similar policies can be introduced for the infrastructure development for EVs to promote and encourage private investment in this sector.

Semi-fast Chargers (20 to 25 kW)

To deploy a semi-fast public charger, the cost breakdown is shown in figure below. To analyse the economic viability, the capital and operational costs are expressed separately.

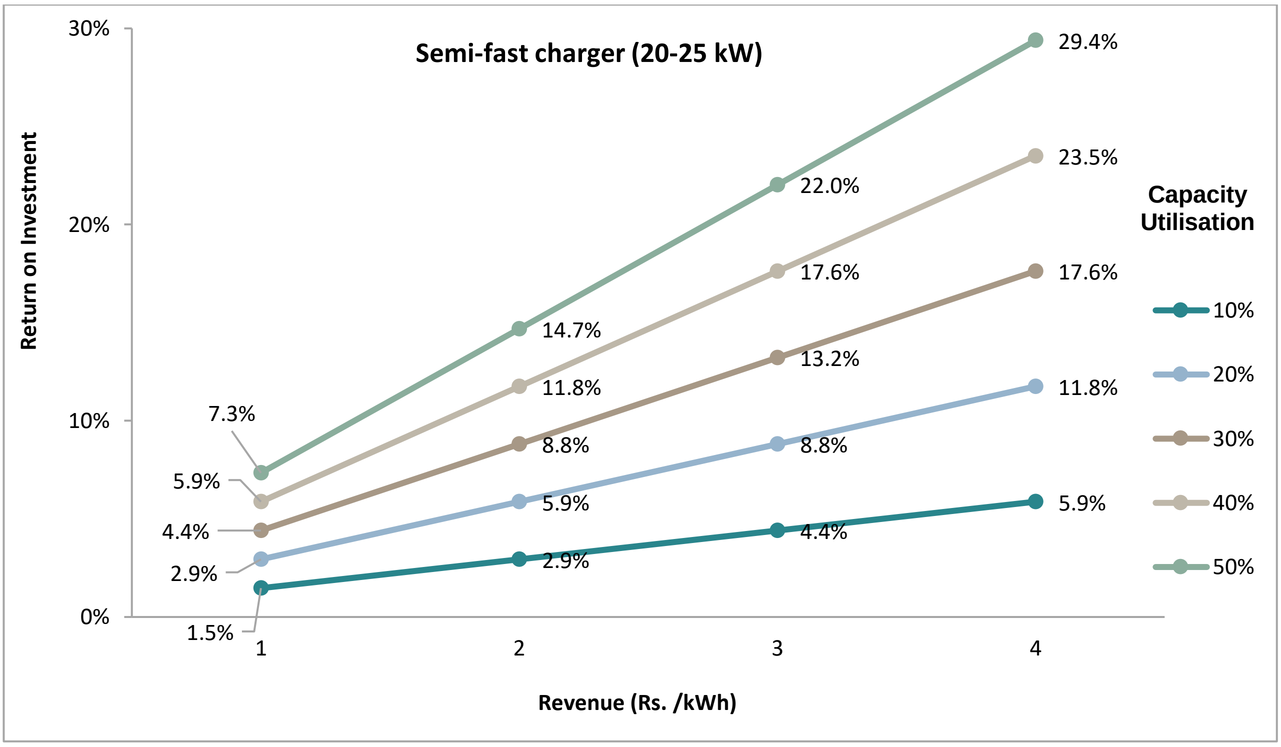
Figure 45: Cost Breakdown of EV Charging Infrastructure – Semi-fast Charger



As shown in the above figure, the CAPEX constitutes 90% and first-year operational cost constitutes ~10% of the amount. With such a high CAPEX, majority of the cost is for the equipment, and the cost of charger is approximately 61%. With government support in terms of subsidies and tax incentives, costs can be reduced to promote the use of public chargers in the initial years. Or, indigenous solutions can be developed locally to reduce the cost of chargers to make them more financially viable. Having seen that, 61% cost is only for a semi-fast charger; a 5% premium tariff for semi-fast chargers for revenue collection is assumed. The premium is given keeping in view two factors: it can supply same amount of kWh in less time and have higher CAPEX incurred.

To get a financial insight, the utilisation factor of each charger is the major indicator to make it financially viable. The graph below shows the return on investment at different utilisation factors.

Figure 46: Return on Investment vs Capacity Utilisation Factor – Semi-fast Charger



The analysis shows the annual return on investment can be higher at higher revenue (PKR/kWh), i.e., 4 PKR/kWh. But at such higher charging costs, EV consumers may be discouraged to use public chargers. Due to high CAPEX, the return on investment has gone down on each utilisation factor while comparing with slow EV chargers. So, a balance will have to be maintained between the return on investment according to the expected utilisation factors. According to the estimates, it is expected the utilisation factor in the initial years can be 10-20%. As the EVs gain traction, the average utilisation factor can be ~30%. As seen in the analysis, for 30% utilisation factor, the nominal revenue per kWh can be PKR 2-3 and the return on investment will be 9-13% respectively

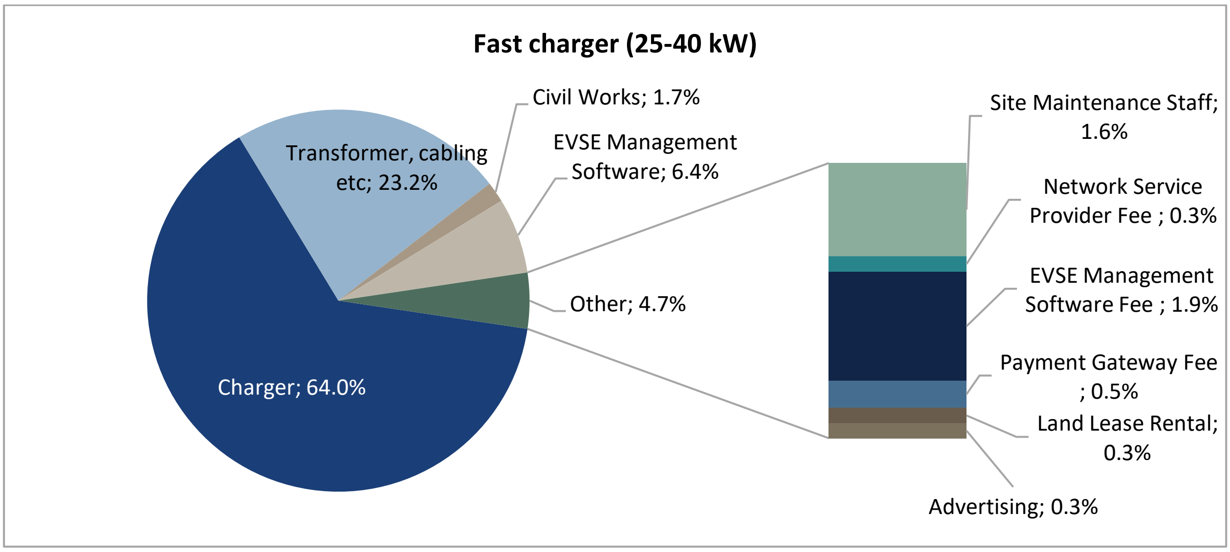
For technology-oriented projects globally, the return on investment is 15-20%. But in the case of semi-fast chargers, the deployment in Pakistan even at 30% utilisation factor brings a maximum return on investment of less than 15%. This category can be viable only if the revenue (PKR/kWh) is beyond PKR. 3/kWh. If the government can offer specialized tariff for EVs, then both the consumer and the investor can benefit, promoting the adoption of EVs in Pakistan. Comparing this business model with renewable energy projects in Pakistan, few projects were committed a return on investment of 17%. Similar policies of fixing the return on investment may be a policy option for semi-fast charger deployment to encourage private investment in this sector.

Another factor of the location of the charger may also impact the 10% increase in capacity utilisation, generating more revenue than calculated. But this will only be true for locations with higher penetration of EVs.

Fast Chargers (25 to 40 kW)

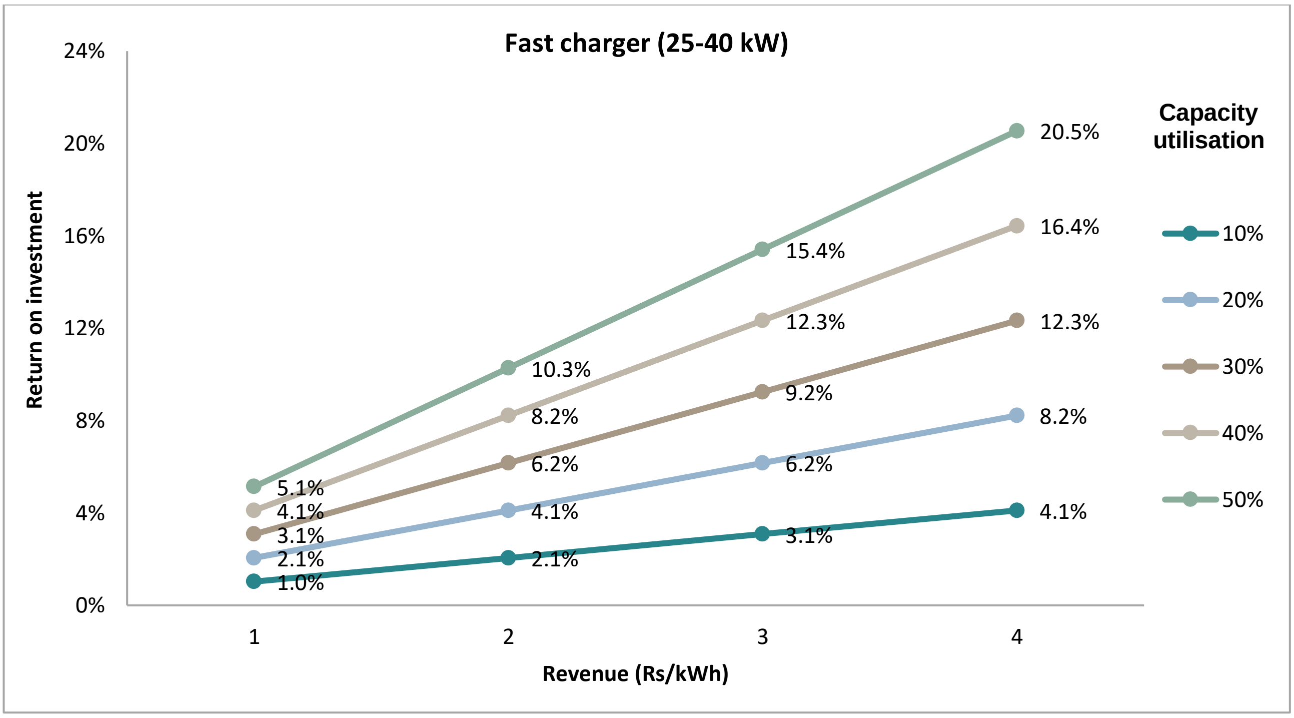
The cost breakdown to deploy a fast public charger is shown in the figure below. To analyse the economic viability of deploying a fast public charger, the capital cost and operational costs are expressed separately.

Figure 47: Cost Breakdown of EV Charging Infrastructure – Fast Charger



As shown in the above figure, the CAPEX constitutes 95% and first-year operational cost accounts for only 5% of the amount. Majority of the cost incurred is for the equipment. The cost of the charger accounts for ~64%, followed by the cost of the transformer, cabling and electric panel. Without government support in terms of subsidies and tax incentives, the costs cannot be reduced to promote the use of public chargers in the initial years. Indigenous solutions can be developed locally to reduce the cost of chargers to make them more financially viable. Considering high CAPEX required for a semi fast charger and distribution transformer, it is assumed to give a 10% premium tariff for fast chargers for revenue collection. The premium is charged by fast chargers because of two factors, first, it can supply the same amount of kWh in lesser time than slow- and semi-fast chargers, and second, the CAPEX incurred is higher in fast chargers.

Figure 48: Return on Investment Versus Capacity Utilisation Factor – Fast Charger



The utilisation factor of each charger is the main indicator of its financial viability. Analysis shows that the return on investment is reducing as moving up from slow chargers to fast chargers, while increasing the charging capacity. To get a nominal annual return on investment, a higher revenue of Rs 4 per kWh is required. However, at such high charging costs, EV consumers may be discouraged to use public fast chargers. Due to the high CAPEX incurred, the return on investment per utilisation factor is lower than slow and semi-fast EV chargers. According to the estimations based on the historical data, the utilisation factor in the initial years is expected to be 5-10% for fast chargers, but as the EVs gain traction and EV density increases, the average utilisation factor could be around 20%. As seen in the analysis, for 20% utilisation factor, the maximum return on investment works out to 8.2%.

For technology-oriented projects globally, the return on investment is 15-20%. But, in the case of deployment of fast chargers in Pakistan, even at 50% utilisation factor, the maximum return on investment would be 20%. This raises the question – Should fast chargers be deployed in a new market or not? Without financial support from the government or equity investment, it would not be financially viable to deploy these fast chargers in Pakistan in the early stages of EV adoption. Over time, when EVs gain good market share, and there is demand for fast chargers, they may become financially viable at premium charging tariffs.

Ultra-fast Chargers (40 kW and Above)

While analysing the fast EV chargers, it is observed that as we move on with higher charger capacity, their financial viability becomes suspected in locations where EV penetration is very less. Due to the high CAPEX involved, they become technically and financially unviable to be deployed in new markets. Another reason for lesser acceptability of ultra-fast chargers is that auto manufacturers have limitations in absorbing high power while charging electric cars. Only few cars are available globally that can absorb more than 20 kW of power while charging. For plug-in hybrid electric cars, the average charger acceptance rate is even lower and not more than 3.3 kW.

Table 85: Battery Capacity of EVs

Sr. No.	Electric Car Model	Battery Capacity (kWh)	Max Power Acceptance Rate (kW)
1	BMW i3	32	7.4
2	Hyundai IONIQ	28	6.6
3	Mercedes B250e	28	9.6
4	Nissan Leaf	40	6.6
5	Tesla Model 3	70	11.5
6	Tesla Model S 60 Dual	60	19.2

Source: BMW, Hyundai Mercedes, Nissan, Tesla

The table above shows that the electric cars available in the market have limitations in accepting power while charging. Even if the charger has a capacity of more than 40 kW, the electric car can only absorb power according to its maximum power acceptance rate. So, at a given point of time, even if advanced technology to charge electric cars in shorter time is available, if it cannot be utilised, it will not be economically viable. But, with improvement in the electric cars manufactured and increase in utilisation of fast chargers, they may become financially viable.

10.5.6 Business Model for Setting up EV Charging Stations

Every technology needs a financial and technical assessment before its implementation. In the previous sections, different indicators have been assessed and their impact has been determined in different scenarios. Different models need to be analysed to come up with the best suitable business model that suits the dynamics of Pakistan's market.

Usually commercial technology-oriented projects are undertaken in public private partnership under the build-and-operate model with private investment. The public parties could be Capital Development Authority (CDA) or IESCO, whereas the private parties could be private investors, auto manufacturers who could be the stakeholders in setting up EV charging infrastructure.

Out of the total EV charging infrastructure setting up cost, the cost of distribution transformer, cabling, etc, constitutes ~25% of the total project cost. If the federal government aims to support this initiative, it can allocate budget for bearing the 25% cost as mentioned above. This will help in reducing the capital required, thus making it more economically viable.

Different modes of implementation have been discussed in the section below. Some light is shed on the possible options which may be practical according to the country dynamics and limitations of electric utilities in Pakistan. The approvals from the National Electric Power Regulatory Authority (NEPRA) may be required for the electric utilities to build and operate EV charging infrastructure. NEPRA may also will have to announce the specialized tariffs for public EV charging stations.

Table 86: Total CAPEX and OPEX Requirements for Potential Locations till 2030 (in Pakistani Rupee)

Description	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total investment
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	
Charger costs	10,392,000	2.340,480	1,779,782	1,486,388	4,363,120	2,922,685	4,459,824	3,283,928	6,464,648	2,108,470	2,793,722	42.4 million
Commercial connection, transformer, cabling (40 meters), panels, breakers, energy meter	14,571,650	2,093,182	1,609,669	404,112	4,646,105	2,610,343	2,363,820	1,332,818	3,835,436	1,472,212	2,713,134	37.7 million
Civil works (flooring, boards, painting, brandings, shed, etc.	1,625,000	344,500	219,102	309,664	738,549	608,893	737,630	684,152	1,346,802	439,265	582,026	7.6 million
EVSE management software - Integration with chargers	1,039,200	234,048	177,978	148,639	436,312	292,268	445,982	328,393	646,465	210,847	279,372	4.2 million
Total CAPEX	27,627,850	5,012,210	3,786,532	2,348,803	10,184,086	6,434,189	8,007,257	5,629,291	12,293,350	4,230,793	6,368,254	91.9 million
Site maintenance staff (1 personnel @15k/month throughout year) (monthly salary * months*number of sites)	1,800,000	2,070,000	2,380,500	2,737,575	3,148,211	3,620,443	4,163,509	4,788,036	5,506,241	6,332,177	7,282,004	43.8 million
Network service provider fee (annual) (monthly subscription * months*number of sites)	270,000	60,000	30,000	60,000	150,000	120,000	120,000	120,000	240,000	90,000	120,000	1.4 million

Description	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total investment
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	
EVSE management software fee (considered as 10% of net margin on electricity charges)	50,625	53,156	55,814	58,605	61,535	64,612	67,842	71,234	74,796	78,536	82,463	0.7 million
Payment gateway fee (1-2% of total money collected) 2.5% in Pakistan	12,656	20,250	32,400	51,840	82,944	132,710	212,337	339,739	543,582	869,731	1,391,569	3.7 million
Land lease rental	214,500	235,950	259,545	285,500	314,049	345,454	380,000	418,000	459,800	505,780	556,358	4 million
Advertising	214,500	227,370	241,012	255,473	270,801	287,049	304,272	322,529	341,880	362,393	384,137	3.2 million
Total OPEX	2,862,281	2,666,726	2,999,271	3,448,992	4,027,541	4,570,269	5,247,961	6,059,537	7,166,299	8,238,617	9,816,531	57.1 million
Total costs	**30.5 million**	**7.7 million**	**6.7 million**	**5.8 million**	**14.2 million**	**11 million**	**13.3 million**	**11.7 million**	**19.5 million**	**12.5 million**	**16.2 million**	**149 million**

Prospective Business Models

Public Private Partnership (PPP)

Effective supply of charging infrastructure is a necessary requirement for the development of EVs and an important strategic measure to promote EV adoption. PPPs may offer a promising way forward and accelerate the development of charging infrastructure by tapping the private sector's financial resources and professional skills.

Charging infrastructure is important for supplying energy to electric vehicles and it needs to be provided in a reasonable manner with a moderately advanced layout. Due to large-scale investment, unclear financing mechanism, interlinked risks, and other factors may be a hurdle for private investors in early stages of deployment of public charging stations. The PPP model may be an effective tool to leverage social capital, ease the burden on local financier enhance the level of project management and profitability, and reduce construction and operation risks.

As there are no clear policy guidelines for EV sales, adoption, promotion, and setting up charging infrastructure, it would be premature for a virgin EV market like Pakistan, to discuss the modalities of the PPP mode such as responsibilities, project planning, construction arrangement, risk-sharing, profit distribution, and supervision at this stage. At the entry level, it is difficult to evaluate market dynamics and forecast sales. Keeping in mind such concerns of private investors, government support may be required to meet revenue gaps in the initial years of EV charging infrastructure deployment. The government may also contribute in terms of financial subsidies, tax preferences, and concessionary credits to promote investment in this sector.

This will be a long-term contract (~15 years) between the public party and the private party, for the development and management of a public asset and services. It is proposed that the public and private parties have an equity share of 70% and 30%, respectively. Both parties are proposed to share the investment and returns with respective ratios. Infrastructure will be developed by a third party through a tendering process as this is the most effective way of project execution. In Pakistan, bureaucratic delays may affect the management and operations of charging stations. Moreover, the public sector also does not have the prerequisite experience for operation and management of such systems. So, it is proposed to give the responsibility of operations and management to the private party. The risk of the project may be undertaken by the public party to attract private party investment in such projects in the early years to stimulate EV growth.

The above-mentioned modalities are proposed, based on the previous PPP mode projects in Pakistan, but the terms of financial expenditure, defining responsibilities in terms of all aspects, operation and maintenance, risk decomposition, and support facilities may be discussed while finalizing the PPP contract for EV charging infrastructure.

If we analyse the table below, and associate the cost with public and private parties, the major investment may be done by the Distribution Company and operations and management can be the responsibility of the private party. There are two key reasons why the public electric utility needs to undertake this investment. The financial risk may be taken up by the public sector enterprise to promote new technology adoption. This will create market acceptance and such initial projects may be trendsetters for the EV market. The other reason is the public utility already has CAPEX planned for installation of distribution transformers and grid expansion for the next 10 years. Some amount from that CAPEX may be diverted to these dedicated projects. This may offset approximately 30% of the total project cost. Some of the project cost may be requested from the federal budget allocation for such innovative future technologies.

Different options can be sorted out to make a viable option according to the country dynamics. But, without clear government support policies and guidelines for EV development, it will be difficult to deploy EV charging infrastructure. Public financing may be phased out after few years once the EV market gains pace and demand is created, then private investment can be encouraged into this sector.

Different investment ratios are shown below to give an idea of investment required by both parties.

Table 87: Total CAPEX and OPEX Requirements for PPP Mode in Pakistan (in Pakistani Rupees)

	Public Partner			Private Entity		
	%age Share	CAPEX	OPEX	%age Share	CAPEX	OPEX
Case 1	70	64,345,830	39,972,818	30	27,576,784	17,131,208
Case 2	60	55,153,569	34,262,416	40	36,769,046	22,841,610
Case 3	50	45,961,307	28,552,013	50	45,961,307	28,552,013
Case 4	40	36,769,046	22,841,610	60	55,153,569	34,262,416
Case 5	30	27,576,784	17,131,208	70	64,345,830	39,972,818

Public sector utilities' involvement in infrastructure development can have numerous benefits, many of which are explored in more detail below:

- Increasing the pace and scale of infrastructure development by opening the market to utility capital, expertise, and other resources
- Maintaining reliability, minimising grid impact, required distribution and transmission system upgrades by coordinating with existing utility investment and planning processes
- Lowering the cost of infrastructure development through coordination with the distribution grid and building on utility experience with infrastructure development

- Improving ability to communicate with customers through existing channels, developing customer pricing models, and creating incentives to promote vehicle charging at times that provide grid benefits—including load balancing and integration of renewable energy sources

But, in the long run, the involvement of public electric utilities could have disadvantages in the eventuality that the government decides to privatize electric utilities, etc. This needs to be addressed by the federal government while drafting EV policies for Pakistan.

Build Operate Transfer (BOT) Model

A BOT project is typically used to develop a discrete asset rather than a whole network. In a BOT project, the private company or operator generally obtains its revenue from a fee charged to the utility/ government rather than tariffs charged to consumers. In the BOT framework, a third party, for example the public administration, delegates to a private sector entity to design and build infrastructure and to operate and maintain these facilities for a certain concession period. During this period, the private party has the responsibility to raise finance for the project, is entitled to retain all revenue generated by the project and is the owner of the regarded facilities. The facility is then transferred to the public administration at the end of the concession agreement free of cost.

The difference between this and the previous model discussed is that, in the previous model, both parties had equity share of the project, but this one is independent of the public utility's involvement. For the agreement period, the private party will invest and locate investment opportunities for funding the project. The government may announce policies such as soft loans for EV charging infrastructure deployment for long periods. This could expand the primary benefits of easy access to capital financing, thus helping to increase the scale of EV charging infrastructure development. It may also oversee other program components, including marketing and host site rental lending, and ongoing operations and maintenance of the infrastructure in a dedicated manner.

Another important component is that with public electric utility support, operation of stations may provide additional opportunities for more sophisticated vehicle-grid integration and the use of dynamic and innovative rates designed to promote grid-optimized charging.

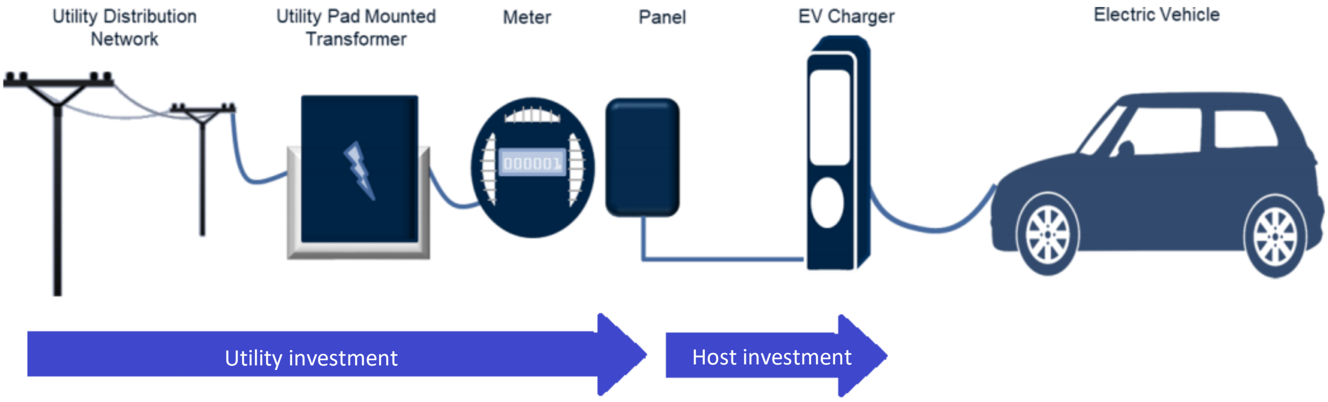
Suggested Business Model

The two business models have been discussed above keeping in mind the country dynamics and the possible options that can be executed with minor changes. After analysing all the indicators and their impacts, a simplified model is suggested for adoption. This model will be more practical to implement, which would require less effort, time and finances for the execution of EV charging infrastructure under the jurisdiction of IESCO. This model may also be adopted by other electric utilities in Pakistan to expand the EV charging network across Pakistan.

If the public utility is principally permitted by NEPRA to develop make-ready locations, such as electricity connection, installing distribution transformers and energy meters, then the host of the potential locations may be convinced to deploy EV chargers, which will decrease a major portion of their cost.

The commercial consumer electricity tariff is the highest among all tariff categories. In case of charging locations which are not owned and operated by IESCO, such sites can still generate revenue because the electric utility may get indirect benefit, treating the public EV charging stations as commercial consumers, thus expanding the commercial consumer base and increasing revenues.

Figure 49: Business Model – Ready-to-build Sites by DISCOs



The remaining investment will only will be that pertaining to site development and charger cost, which will not be much for a private entity to bear, when expecting good return on investment. And, to attract more private parties, the government may announce soft loans and provide subsidies for such projects.

The operations and management of the sites will be the responsibility of the host of the EV chargers, the maintenance can be sublet to service companies and these costs can be incorporated in the tariff models.

After analysing different modalities, it is observed that interference of government is required in two parts i.e. policies for EVs and tariff structure for EV charging. As the tariff structure is designed by the regulator, all stakeholders may need clear direction before planning for such projects.

Costs Associated with a DISCO

Different business models and CAPEX requirements in general have been discussed in the above sections. The DISCOs have limitations of doing business under their license category. IESCO officials have no clear directives for doing a separate commercial activity under the same license. The regulatory authority and the government will have to announce new mechanisms that can be adopted by the electric utilities.

According to the electric utilities, delivering ready-to-build sites is a more practical approach to give a push-start for setting up charging infrastructure in the licensee area. Planning, site identification and required budget have been chalked out in coordination with IESCO for each potential location. If the electric utility has to build the charging infrastructure the cost breakdown of each site is mentioned in the table below.

Table 88: Associated Cost Breakdown by a DISCO for Potential Locations (Pakistani Rupee)

Year	Potential Location	Cost of Chargers	Cost of Distribution Transformer	Cost of Wire/ Panel/ Energy Meter	Cost of Connection/ Installation & Civil Works	Total Expected Cost
2020	Airport	1,584,000	1,099,750	817,600	225,000	3,726,350
	Bahria Town Civic Centre	312,000	174,500	342,600	85,000	914,100
	Centaurus Mall	1,584,000	1,099,750	817,600	225,000	3,726,350
	F- 9 Park (Mega Zone)	624,000	870,000	532,600	155,000	2,181,600
	G-5 Government Offices	936,000	1,099,750	817,600	225,000	3,078,350
	Jinnah Park	936,000	870,000	532,600	225,000	2,563,600
	Murree Road - Metro Park & Ride	1,896,000	1,099,750	817,600	295,000	4,108,350
	Saddar Parking Plaza	1,896,000	1,099,750	817,600	295,000	4,108,350
	Shifa International Hospital	624,000	870,000	532,600	155,000	2,181,600
2021	Giga Mall RWP	624,000	174,500	342,600	155,000	1,296,100
	Saidpur Cultural Village	1,584,000	870,000	532,600	225,000	3,211,600
2022	Daewoo Terminal	1,584,000	870,000	532,600	225,000	3,211,600
2023	DHA Main Market	312,000	136,700	167,600	85,000	701,300
	G-5 Government Offices	936,000	-	-	210,000	1,146,000
2024	E-11 Markaz/ Marquees	624,000	174,500	342,600	155,000	1,296,100
	Fawara Chowk Parking Plaza	624,000	174,500	342,600	155,000	1,296,100

Year	Potential Location	Cost of Chargers	Cost of Distribution Transformer	Cost of Wire/ Panel/ Energy Meter	Cost of Connection/ Installation & Civil Works	Total Expected Cost
	Islamic University	312,000	136,700	167,600	85,000	701,300
	Lake View Park	1,584,000	1,099,750	817,600	225,000	3,726,350
	NUST University H-12	312,000	136,700	167,600	85,000	701,300
2025	COMSATS University	312,000	136,700	167,600	85,000	701,300
	NARC	624,000	174,500	342,600	155,000	1,296,100
	PIMS Hospital	624,000	174,500	342,600	155,000	1,296,100
	Pir Sohawa/ Daman e Koh	624,000	174,500	342,600	155,000	1,296,100
2026	Airport	1,584,000	-	-	210,000	1,794,000
	Centaurus Mall	624,000	-	775,000	140,000	1,539,000
	Polyclinic Hospital	624,000	174,500	342,600	155,000	1,296,100
	PWD Main Market	312,000	136,700	167,600	85,000	701,300
2027	F- 9 Park (Mega Zone)	624,000	-	-	140,000	764,000
	Lok Virsa	312,000	136,700	167,600	85,000	701,300
	NESCOM Hospital	624,000	174,500	342,600	155,000	1,296,100
	Saddar Parking Plaza	624,000	-	-	140,000	764,000
2028	Daewoo Terminal	624,000	174,500	342,600	155,000	1,296,100

Year	Potential Location	Cost of Chargers	Cost of Distribution Transformer	Cost of Wire/ Panel/ Energy Meter	Cost of Connection/ Installation & Civil Works	Total Expected Cost
	F -11 Markaz	624,000	174,500	342,600	155,000	1,296,100
	Fast University	312,000	136,700	167,600	85,000	701,300
	G-9 Markaz	312,000	136,700	167,600	85,000	701,300
	I - 8 Markaz	312,000	136,700	167,600	85,000	701,300
	Lake View Park	936,000	-	-	210,000	1,146,000
	Metro Cash & Carry	312,000	136,700	167,600	85,000	701,300
	Murree Road - Metro Park & Ride	624,000	-	-	140,000	764,000
2029	F-7 Markaz	624,000	174,500	342,600	155,000	1,296,100
	Jinnah Park	312,000	-	-	70,000	382,000
	PIEAS + Nilore	312,000	136,700	167,600	85,000	701,300
2030	Abpara Market	312,000	136,700	167,600	85,000	701,300
	F -6 Markaz	624,000	174,500	342,600	155,000	1,296,100
	G-10 Markaz	312,000	136,700	167,600	85,000	701,300
	Westridge	312,000	136,700	167,600	85,000	701,300

The total CAPEX required by IESCO to set up ready-to-build sites for the period of next 10 years will be approximately 70.4 million PKR. IESCO has allocated 12,294 million PKR for their Distribution System Expansion (DOP) activities. The required amount for setting up charging infrastructure is just 0.6% of the planned DOP budget for the next 10 years. This shows how easily an electric utility can develop the sites to support the uptake of EV charging infrastructure. The government's support and commitment may also be required as electric utilities have limitations. To make the case of EVs stronger in Pakistan, all stakeholders should be involved in the process and show commitment to push-start the emerging EV market in Pakistan.

Sources of Funds Required

All the power utility companies submit their short, medium and long-term plans to the regulatory authority for validation. A combined meeting of all DISCOs is arranged by the Central Power Purchasing Authority (CPPA), National Transmission and Distribution Co. (NTDC) to map all the future demand, forecast load profiles and upgrades required to cater to the load growth. The planned CAPEX is also submitted to the regulatory authority after combined planning efforts.

A tariff petition by each electric utility is submitted to the regulatory authority, in which, indicators such as decrease in losses, expected revenue collection, margin (PKR/kWh), planned CAPEX, etc., are characterized for a period of 5 years and is revised every year, if needed. Based on the figures provided by the electric utility, the regulatory authority approves a tariff for the electric utility. The approved tariff is broken down, out of which, some portion is dedicated towards the CAPEX for upgradation, expansion and maintenance activities. For the above-mentioned regular activities, all the power distribution companies generate their own funds. But, for extra projects such as evacuation of a large power plant, special economic zones, etc., the funds are provided by the federal government under different financial mechanisms. For specialized projects, the utilities also seek financial grants from Asian Development Bank (ADB) and World Bank. Some projects have also been financed by development agencies such as United States Agency for International Development (USAID), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), etc, in the past.

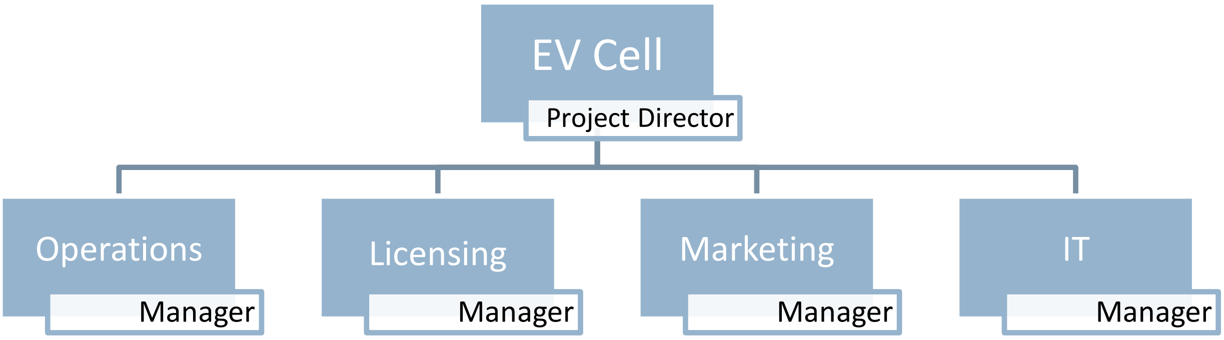
According to the statistics provided by IESCO, they have planned CAPEX for the next 10 years till 2029 under three different heads. The total CAPEX planned for expansion, upgradation and maintenance is approximately 44,256 million PKR. In the next tariff petition, IESCO may incorporate the cost of setting up the necessary infrastructure for the EV charging stations. Resources may be sought from the federal government for infrastructure development of EV charging stations, or they can be financed by development banks as done in the past for specialized projects. Another option is to submit a PC-1 to the government, so as to get budget allocation for EV charging infrastructure development.

10.5.7 Organisational Capacity Planning

Organizations in both private and public sectors are finding themselves having to struggle with increasingly complex projects and programs, in the face of more demanding customer requirements, rapid technological advances, and the continuing intensity of pressure to perform better. Usually public sector organizations are reluctant to invest in the capacity building of its workforce.

In Pakistan, CPPA arranges in-house training programs for the employees of electric utility companies, and public power generation companies. For dedicated projects such as power sector reforms that was funded by USAID, they had a dedicated module to train the staff of the planning department of each DISCO according to the new system designs. Similarly, when the net metering policy for renewables was announced, the National Electric Power Regulatory Authority (NEPRA) trained the net metering cell staff of each DISCO. Apart from these trainings, electric utilities have different programs to train their staff under different categories.

For the EV infrastructure, each utility will have to create a separate cell. They will require a range of skills and attributes from their staff with capabilities for both planning and implementation of the project. The suggested hierarchy may be required for successful implementation of the EV programme.



The EV cell will be headed by the project director. Under this cell, four dedicated departments under the supervision of managers are suggested that would be required for smooth operations.

Operations: The operations department will be responsible for the installation and maintenance of the designated sites. The department will be led by a manager followed by assistant manager, support staff and technicians. The team may be expanded according the requirements in future.

Licensing: The licensing department will be responsible to liaison with the commercial connections department of IESCO and issue license to the EV charging sites in case of privately owned EV charging stations. The department will also have to interact with NEPRA for tariff petitions and legal matters. They will be responsible to coordinate with the planning department for future load growth and other activities for long- and medium-term planning. The department will be led by a manager followed by assistant manager and support staff. The team may be expanded according the requirements in future.

Marketing: The marketing department will be responsible for awareness campaigns in public, advertisement and other related activities. It is very important to establish this department to ensure that the new technology adoption awareness is publicized in a professional manner. The department will be led by a manager followed by assistant manager, a public relation officer and support staff. The team may be expanded according the requirements in future.

IT: The IT department will be responsible to setup internet connectivity, installation and troubleshooting of softwares of EV chargers, online billing system etc. They will also coordinate with the internet service provider for smooth operations. They may also need to setup an online monitoring system of all the EV charging stations under the jurisdiction of IESCO. The department will be led by a manager followed by assistant manager, networking expert, and support staff. The team may be expanded according the requirements in future.

All these departments will have to work in close coordination with other departments of IESCO such as procurement, billing, accounts etc.

In IESCO, capacity development program is a part of the central HR system designed to ensure that the electric utility has a coherent way of assessing and planning how it will ensure that its staff has the skills, knowledge and abilities it needs to successfully deliver its goals and objectives. To ensure successful implementation of the EV program, IESCO will require the following upgrades in terms of organizational capacity enhancement:

- Understand the nature of complexity, and the skills necessary to manage the implementation of the EV program
- Develop role and skill profiles of staff relative to the requirement of the project
- Ensure the team managers have proper project management skills in order to achieve the KPIs
- The planning staff should be trained to analyse the impact on grid, site evaluation, etc.
- Monitoring, evaluation and audit team to be trained for the program
- Dedicated team of software management staff to be trained according to the country dynamics

Will/Vision /Strategy of Management

The future of electric utilities sustainability is planning for future. Good engineering judgment and technological advancements, however, will prevail as future system requirements are defined. As per the analysis done for electric utilities across Pakistan, among all 11 DISCOs, IESCO was the top performing DISCO.

After the engagement with the officials of IESCO, their commitment to grow, deliver and ensure customer service was evident. Below are the details of their vision, mission, customer satisfaction and employ development are as follows:

Vision

To be the most admired public utility in Pakistan, an undisputed leader in the power sector, efficient and profitable.

Mission

To provide uninterrupted power supply to our customers enabling trade and industry, commerce, educational & social activities to flourish and enrich the lives of our customers.

- To be the most efficient public utility in Pakistan.
- To achieve the lowest line losses in the distribution sector.
- To generate profits for our stakeholders.
- Acquire, learn and apply state-of-the-art technology
- Have well-defined SOPs with specific ownerships and accountability.

Customer Satisfaction

- Continuously improve quality of service and responsiveness to maintain a satisfied customer base.
- Demonstrating professionalism in all customer dealings and ensuring that all business actions are driven by customer needs.
- Improve reliability and efficiency of supply of electricity to the customers.

Employee Development

- Improve skill set of employees according to market demands.
- Focus on recruiting, developing and retaining best professionals.
- Empower people to maximize their potential and contribution.
- Promote open and honest communication.
- Fill the competency gaps within the organization.

Staff Exposure and Expertise of EVs

Workers from a variety of educational and employment backgrounds are employed in the electric utilities in various departments. All the departments have trained staff for required skill sets. Electric utilities comprise of teams of project managers, engineers, sales & marketing experts, technicians etc., who look after day to day matters as well as medium- and long-term planning. Team leaders, project directors and higher authorities have experts with very diverse experiences who have managed large scale new initiatives, its project designing, financial modelling etc.

As the adoption of EV's roll out, the electricity demand, requirement of charging infrastructure will increase, and integration of public chargers with centralized communication will also be required. With these requirements of manpower/experts, the electric utilities will also need to enhance the capacity of their staff accordingly.

On discussion with the IESCO officials, they have experts working in all departments who are associated with different projects and programmes with required aforementioned expertise. They have a dedicated department and expert teams in the following domains:

- Planning and execution of power distribution, transmission system
- Procurement of equipment and supplies
- Engineers and technicians for troubleshooting, operation & maintenance of power system
- Policy and regulatory matters

But even having said that, IESCO has expertise to cater to the technology of EV's, they would still require to enhance the capacity of their existing employees. Apart from capacity building of employees, they would also require to hire few experts dedicated for the EV program.

IESCO/electric utilities in Pakistan would require to have trained technical staff in the domain of accessing the impact on grid because of EV charging, the technology for public chargers, communication system to analyse the performance/occupancy of public chargers etc. IESCO/electric utilities may also require the following to be successful in supporting the role out of EV's:

- Conduct internal education on EV's, especially for leadership
- Understand industry and technology trends, stakeholder's views on EV's
- Designate staff/team to focus on EV's
- Explore partnerships with municipalities, industry organizations, equipment manufacturers.
- Conduct deeper financial and system modelling to assess impacts of EV adoption
- Build partnerships or programs with original equipment manufacturers or dealerships

Organisational Planning to Promote Use of EV Among Consumers

Strategic planning helps the electric utilities to identify the direction where they need to go and what's the best way to achieve their goals. The electric utilities have separate departments to perform their specialized tasks such as power planning, load forecast, operation & maintenance and outreach programs. Utility's policy implementation is planned in such a way, to see if they reflect the needs of their customers, ensure regulatory compliance, and generate sufficient financial resources to be sustainable.

IESCO has a separate department for outreach of their initiatives and activities. To support and promote new initiatives proper strategy is devised for all the programs. Without a strategy a to help connect more vehicles to the grid, IESCO will see slow growth and lower occupancy levels at public charging stations resulting in lower return on investment. Marketing and promotion of available public charging station, incentives on public charging and monetary benefits will be some initial steps for the promotion of public EV charging infrastructure.

The planning to promote the use of EVs would require the engagement all the stakeholders i.e. planning team, sales & marketing team and IT services team to develop a combined strategy to disseminate the information regarding the adoption of EV's among the consumers. Below are few of the recommendations to off take and promote the initiative of EV charging stations:

- Promotional campaign on official website
- Promotion through consumer electricity bills
- Roadshows in different locations of IESCO jurisdiction
- Engagement with Capital Development Authority (CDA)
- Social Media Cell for promotion and outreach of the EV Program
- Pilot Project with free EV charging
- Engagement with Auto Manufacturers for compatibility of EV charging equipment
- Engagement with regulatory authorities for development of Rebate programs for EV purchase and vehicle charging

11 Benchmarking with International Utilities

In order to devise action plans for the 3 utilities in India, Pakistan and Bhutan, a benchmarking study has been done on international utilities, which have been industry leaders in adopting e-mobility programs. They are as shown below.

Name of Utility	Consumers Energy (CE)
Region	Michigan
Country	US

CE has been a strong promoter of EV and e-mobility in the Michigan region. It has been incentivising the deployment of EV chargers at homes, apartments, schools, workplaces and other public places. The utility is also working closely with automakers like Ford and General Motors as well as the local government to build a strong EV ecosystem.

Pricing Strategies:

1. The utility was one of the first companies in the US to offer special charging rates for EVs. It had also piloted an incentive programme for home charging stations
2. Presently, the utility has several pricing programmes for EV owners, who intend to use home charging. It has a standard rate plan, where charges are levied based on normal rates, and a residential time of day plan, where special time of day charges are levied if EV is charged during off-peak hours (lower-cost evening, early morning and/or weekend hours)
3. Through its PowerMIDrive rebate programme, a 3-year $10 million effort, Consumer Electric provides rebates for drivers to install EV charging stations at their homes, and to businesses who install public chargers

   The rebate programme includes the following:

   - Rebates for residential EV owners of $400-500 for installing eligible 240 V chargers at homes across the state. So far, 35 rebates for home chargers have been approved
   - Rebates for 200 Level 2 vehicle chargers in public places and at workplaces throughout Michigan, with a rebate of up to $5,000 per charger
   - Rebates of up to $70,000 for 24 DC fast chargers along highways and travel routes in Michigan, working with state-wide entities to ensure a unified network across the state. As part of the programme, close to 125 rebates for EV charging stations across Michigan, worth $5,000 apiece, have been approved

4. Low off-peak electricity rates between 7 pm and 6 am, and a super off-peak period of 11 pm to 6 am, to encourage drivers to charge at night when power is cheap and plentiful, and to avoid charging during peak afternoon or summer hours. Up to 3,000 of those who sign up for the special rate also can also receive a $500 rebate for each EV.

CAPEX programmes:

1. CAPEX programmes are funded majorly by the utility along with occasional state and donor support. Funding a CAPEX-intensive programme like incentivising and installing EV chargers needs resources. And this has been obtained majorly through rate hikes
2. The utility typically recovers the EV programme costs over a longer tenure through a deferred accounting mechanism. With the help of targeted awareness and advertising, the utility expects recovery to the tune higher uptake of EVs will materialise sooner than expected. Through continuous investments in demand response measures and energy efficiency initiatives, consumers intend to improve supply and service, thereby creating a stick effect among customers and businesses
3. For the latest PowerMIDrive, the Michigan Public Service Commission has approved a rate increase to help fund the programme and other utility activities. As per estimates, this translates into an increase of $1.62 per month for a residential customer who uses 500 kilowatt hours of electricity

Name of Utility	New York Power Authority
Region	New York
Country	US

The New York Power Authority (NYPA) is the largest state public power organisation in the US, operating 16 generating facilities and more than 1,400 circuit miles of transmission lines. The NYPA has been instrumental in developing and encouraging EV charging ecosystem in the country. Through its innovative programmes including EVolve NY, the utility intends to address infrastructure and market gaps and advance the adoption of EVs in the New York state. Close to 200 DC fast chargers will be deployed in airport charging hubs, along interstate highways and communities at an initial investment of $40 million. The state has a goal of installing at least 10,000 charging stations by the end of 2021.

Pricing Strategies:

1. With most of the charging stations being built in New York's investor-owned utility territory (Con Edison, Orange and Rockland, Central Hudson, Niagara Mohawk, New York State Electric & Gas and Rochester Gas & Electric), it ends up paying demand charges to the Public Service Commission. The

NYPA has been negotiating with the commission to reduce demand charges, at least till the time adoption rates improve

2. Time of use charges, introduced by the Public Service Commission in early 2019, will apply to The NYPA and will improve EV charging behaviour through load shifting to off-peak hours.
3. The NYPA works in tandem with the New York state to improve EV adoption. Under the Drive Clean Rebate programme, more than 11,000 rebates, totalling over $15 million, have been approved by the state to help New Yorkers to purchase e-cars. The NYPA complements the EV buying behaviour through rapid charging infrastructure development

CAPEX Programmes

- The NYPA has been 'the first mover and the first tester' of new clean-tech initiatives like EV charging. As the utility is government controlled, it has access to state funds and resources in addition to internal accrual. Additional taxes levied on gasoline-powered vehicles, like congestion taxes, are collected by the state and partially passed on to the utility to drive EV programmes
- In addition to internal resources, the NYPA receives funding through university grants, the Department of Energy and other multilateral agencies to drive CAPEX-heavy EV programmes. In 2018, the utility received $2.67 million in funding from the Department of Energy along with the ABB Group and North Carolina State University to develop an intelligent, grid-friendly, modular, extreme fast charging system for EVs
- The EVolve NY programme, which is a $250 million commitment through 2025, will initially be driven by the NYPA in the first phase and subsequently delivered through public-private partnerships

Name of Utility	Électricité de France
Country	France

The state-controlled utility, Électricité de France (EDF) aims to be a leader in e-mobility in Europe. Its target is to achieve 30% market share in EV charging in France, Belgium, Italy and the United Kingdom (UK) by 2022. The company's subsidiary, Izivia (ex-Sodetrel) already operates ~5,000 charge points and has access to 60,000 more for customers with a Sodetrel Pass. EDF intends to operate 75,000 EV charging stations in Europe by 2022.

Pricing Strategies

A. The utility sells the entire bouquet of products from EVs to home chargers along with complementary installations. It charges consumers based on standard, ToU or customised V2G rates

B. EDF runs the Workplace Charging Scheme for charger installations at workplace, which allows businesses, charities and local authorities to claim 75%, up to a maximum of £500, of the total cost of a charging station, with a maximum of 20 sockets per site. Eligible businesses are given subsidy support

CAPEX Programmes

1. Most charging stations are installed in cooperation with e-mobility partners and municipalities, via car-sharing EV service providers, or partnerships with private companies and e-mobility partners. This revenue-sharing model helps improve project viability and profitability
2. The utility has made several strategic partnerships with firms in the e-mobility space. These include V2G startup Nuvve (a San Diego-based startup that intends to roll out 1,500 V2G-capable chargers in the UK), and European EV-roaming platform GIREVE
3. EDF, along with Germany's E.ON and Italy's Enel (both major e-utilities), has been collaborating with Nuvve and Nissan on V2G pilots in Europe
4. The utility major has also entered into partnerships with auto manufacturers like Renault and Toyota, where both parties mutually work towards enhancing EV sales and deepening the market
5. EDF and Valeo, the leader in high- and medium-voltage electrification, have formed a partnership to monitor the development of future battery technologies and charging solutions, as well as the development of mobility service
6. EDF and German-based start-up Ubitricity, through a partnership model, have developed solutions to convert existing streetlights into charging points and have delivered several projects in Europe and across the world. Citelum (100% affiliate of the EDF Group) and Ubitricity have also been partnering to integrate this solution with Citelum's 'Smart City' range of products

12 EV Traction in Other SAARC Member States

12.1 Bangladesh

With no EV registration guidelines in the country present, there is no official figure of EVs plying in the country. The Bangladesh Road Transport Authority has drafted guidelines on EVs stipulating registration, fitness certificate and tax token in January 2019. However, there are close to 1 million battery-powered three-wheelers called Easy Bikes plying in the country. With absence of widespread PCSs in the country, they are charged in households or from illegal outlets of 11 kV. This has led to a loss in revenue and pressure on the power grid. There are about five charging stations for Easy Bikes, with all of them being solar powered. While the Bangladesh Rural Electrification Board has installed two charging stations, the Bangladesh Power Development Board, Dhaka Power Supply Company, Dhaka Power Distribution Company have each set up one charging station each. The charging stations are located in Chittagong, Sylhet and Keraniganj. The stations have been set up as pilot phase, and a lumpsum amount is charged for each usage at the stations. At present, the distribution utilities do not have any plan to develop PCSs in the country due to lack of federal policies as well as end-use EVs on the roads.

Policy front: Bangladesh Road Transport Authority (BRTA) has issued draft guidelines on EVs, making registration, fitness certificate and tax token mandatory. The draft policy also specifies the lifespan of various modes of electric mobility — two wheelers, three-wheelers, and light and heavy-duty vehicles.

Tax incentives: Recently, government has been promoting hybrid vehicles by providing substantial tax incentives, apart from having various tax exemptions for electric two wheelers and three wheelers.

Promotion of charging infrastructure: Bangladesh Energy Regulatory Commission (BERC) has introduced a new tariff category for charging stations – setting energy charge of 7.70 Tk./kWh along with an additional demand charge of 40 Tk./kW/month. In addition, Bangladesh Rural Electrification Board (BREB) is installing solar powered charging stations, hence promoting renewable energy for EV charging stations.

Challenges towards fast adoption of e-mobility:

- Lack of charging points across the country
- Lack of fiscal incentives and supportive policy measures for import of Li-ion batteries and local production
- No mandatory procurement of EVs for players having large vehicle fleets
- No soft loan facilities given by the government to operators for buying e-buses
- Electric 2W and electric 3W have incidental taxes of 89.4% each. Further reduction may be required to improve sales traction

Potential Models for EV charging infrastructure development

The country is in a very nascent stage to develop a model for EV charging station development. The government needs to put impetus for initial market development. The major chunk of EVs are 3W operating on its rural roads, which can be charged through home-based chargers at night or when they are not plying on the road. However, charging stations at strategic locations (stands/ depots) can help increase running time of the 3Ws, if the charging time is not high and do not hamper business. The government can look tying up with e-3W manufacturers, distribution utilities through a Joint Venture (JV) to develop charging infrastructure, which can in turn push more e-3W sales. The JV can look at mobilising funds through government grants, CAPEX programs of utilities as well as manufacturers to set up charging stations. While the PPP mechanism will allocate funds, O&M can be outsourced to interested parties. As more and more EVs begin plying on the roads, the distribution utilities can look at entering full-fledged EV charging station business. However, policies pertaining to cost of electricity at the station, standardization of chargers and other modalities need to be ironed out before the private entities may want to enter the business.

12.2 Sri Lanka

There are ~4,600 EVs plying in the country. In order to complement the EV growth, several MoUs and tie-ups have been made in the last few years, with Japanese company Electore and Swedish manufacturing major ABB for increasing PCS installations. Presently, the country has 30-50 charging stations, mostly operated by private players. The Ceylon Electricity Board has set up two charging stations in Kandy and will set up another three in Nuwara Eliya, Kegalle and Dambulla. Further, ABB will set up six DC fast chargers in Colombo city. Lanka IOC PLC, Sri Lanka's privately owned petroleum distributor, is planning to set up close to 12 charging stations, mostly at their retail outlets. The government has taken a strategic decision of setting up 100 EV charging stations in the country by 2020.

Policy front: Sri Lanka announced plans to replace all state-owned vehicles with electric or hybrid models by 2025, a move that will be extended to private vehicles by 2040.

Tax incentives: The government has evinced interest to cut taxes on EVs by at least one million rupees. Furthermore, import duties on EVs, including 3W and buses is also expected to be reduced. The government has also slashed taxes on EVs from 25% to 5% in its interim budget of 2015. On the contrary, import duties for conventional vehicles will be increased by ~50,000 rupees. A carbon tax has also been proposed at around 17 Cents, 1.78 rupees and 2.74 rupees per day for a motor cycle, car and a passenger bus respectively.

Promotion of charging infrastructure: The Sri Lankan government has made a strategic decision to install more than 100 EV charging stations by 2020 to align with the country's plan to obtain a minimum 20 percent of its energy from renewable sources. The Government has empowered Public Utilities Commission of Sri Lanka (PUCSL) to establish a register of EVCS at each distribution licensee- CEB and LECO, issue code of practice for EVCS, determine end user tariffs, issue safety and other technical standards for EVCS. Privately owned charging stations have been encouraged, with ~75 such stations existing in the country. ABB is developing the country's EV fast charging infrastructure with more than 10 CCS and CHAdeMO compatible chargers deployed till date in Colombo and the greater Colombo areas, as well as a few other major locations including Kandy, Kurunegala and Kegalle

Challenges towards fast adoption of e-mobility:

- Despite tax concessions on EVs, taxations are inconsistent across EV categories. The Government had offered tax concessions on EVs with a motor capacity of 70 Kilo-watts (Kw) or below as well as exempting EVs from the new carbon tax. However, vehicles with a capacity of over 150 Kw are hit with a 150% tax making imports of most EVs not competitive or feasible.
- Lack of necessary charging infrastructure to use an EV in the country.
- Lack of government program to dispose, recycle or export used batteries. Additionally, regulations in Sri Lanka prohibit the import of used batteries. This affects resale values of EVs

Potential Models for EV charging infrastructure development

The island nation is self-sufficient in its power needs. This gives an opportunity for the country for accelerated development of EVs. The charging stations set up in the country have majorly been through private investments. Although the Government has encouraged electric mass transportation in cities like Colombo and Galle, deployment is slow. A public-private partnership model between government and private parties can help improve development of EV charging stations in the country. Presently, no distribution utility has entered into EV charging business. The number of EVs on the road are small for a positive business case. Therefore, the initial push through subsidies, grants from the government can help garner interest from utilities. The utilities do not have experience or expertise to enter into the business though the full ownership mode. Private investment along with government stake can help garner utilities' interest.

12.3 Nepal

The government, in a bid to promote EVs in the country, has set out a target of setting up 200 EVCSs in the country. The Nepal Electricity Authority (NEA) will be responsible for building the stations and providing electricity for the same. In May 2019, the NEA had sent out a notice seeking to rent land for building 10 EVCSs. With the country expected to be power surplus by fiscal 2021, the NEA expects to set up additional charging stations in Pokhara, Nepalgunj, Chitwan and Biratnagar along with the capital city Kathmandu. Additionally, Kathmandu plans to replace its entire fleet of gasoline-powered buses with e-buses by 2030.

Policy front: As per a new action plan, the government intends to turn at least 20% of public vehicles into EVs by 2020. After the country becomes power surplus through hydropower, it aims to make electricity cheap enough to make EVs more viable commercially, thereby displacing dirty and imported fuel with the domestically-generated clean energy.

Tax incentives: To further accelerate EV growth in Nepal, the government has reduced import duties on public EVs to 1% from 30% and on private EVs to 10% from 30%. Additionally, EVs are exempt from road tax, which can be Rs 30-50,000 per year for fossil-fuel cars. No excise duties are levied on EVs as well. While the retail price of petrol and diesel reaches up to 261% above the cost price, electric vehicles carry just a 10% tax on the purchase price. Electric cars are exempt from road tax, which can be Rs30-50,000 per year for fossil-fuel cars. Nepal is the only country in the world with such a huge relative tax difference.

Promotion of charging infrastructure: The Government intends to o set up more than 200 EV charging stations across the country over the next 2-3 years. The stations will be operated in places such as government offices, parking areas of public schools and other public areas. The proposed stations will recharge EVs using any of the three ports – CHAdeMO, CCS and GB/T. Presently, Cimex Inc. has installed 12 charging ports while Korean auto manufacturer has set up 2-4 charging stations.

Challenges towards fast adoption of e-mobility:

- High cost of charging stations: A fast-charge electric station costs a minimum of $30,000 and can charge only 25 vehicles a day. Establishing one requires a government subsidy as well as a regulator to permit the charging of different EV models
- Lack of tax incentives for bikes and scooters similar to those for private cars. Kathmandu Valley alone has 750,000 motorcycles and any tax breaks towards e-bikes may help improve sales
- Lack of policies for electric public transport. Although local and provincial governments had shown an interest in providing financial support to develop electric public transport, concrete plans have not been made yet. The high investment cost of electric public transport requires government to step in with subsidies. Despite revenue from the petroleum tax has grown to a whopping Rs. 5.2 billion, not much is invested in a clean-energy electric transportation strategy

Potential Models for EV Charging Infrastructure Development

The country, with its rich hydropower potential along with rising EVs, has a strong case of going green from generation to consumption. Presently around 4-5 charging stations exist in the country, all of which are privately owned. Of late, the government has shown interest with Nepal Electricity Authority planning to install close to 50 charging stations across all seven provinces in the country. Model of development, in the initial phase, will be driven by CAPEX allocation from the government and interest from private stakeholders. The government can give land to station developers at concessional rates as well as enable setting up of necessary infrastructure (transformer, meter etc.). Through a viability gap funding, more private investments can be mobilized. However, the role of state as owner-operator is not expected to be viable in the initial stages of market development. Utilities can tie up with major EV players whose models are in use in the country to co-develop charging infrastructure. As acceptance of EVs improve and public transportation begin moving to EVs, the role of utilities and government can be increased, based on business viability.

12.4 Afghanistan and Maldives

There have been no major developments so far in these two countries in the e-mobility space. Maldives intends to be a part of the Global Electric Mobility Program to understand and develop demonstration projects in the e-mobility space. Afghanistan, given the present state of the economy, is not in a position to adopt EVs anytime soon.

13 Annexure

13.1 Overview of Meetings and Discussions Held

13.1.1 Bhutan

Meeting with EV Taxi Drivers and Users

The meeting was held in order to understand the issues faced by EV taxi drivers in the country. The issues raised in the meeting are:

- Encouraged to use EV due to free charging
- Need more no of EVCS at different locations
- Need of separate parking space for EVs
- Limited mileage of EV battery
- High maintenance cost
- Difficult to get EV spare parts
- Subsidy from government could encourage more EV users
- To avoid monopoly of EV supply.
- Need of twin EV chargers in one EVCS
- Not ready to pay for charging EV
- If required to pay for using EVCS, then there will be limited or no users switching over to EV
- Taxis prefer fast chargers to slow chargers
- Need for home chargers as a backup
- Need to retrofit existing buildings to accommodate home chargers

Meeting with EV Project Manager and Team from College of Science and Technology (CST), Phuntsholing, Bhutan

Following issues were discussed briefly:

- EV is multi-sectoral project.
- EV project in Bhutan is targeted to replace taxi fleet.
- One of the important parameters for taxi is mileage per full charged battery.
- Minimum mileage for EV in Bhutan would be 200 km.
- EV specification finalized.
- Proposal to provide 20% of the total cost subsidy to the taxi.
- A total of 300 taxis to be supported.
- 23 charging stations in three years.
- Operational modality of EVCS is not yet decided.
- Received enquiries from private individuals for subsidy.
- No subsidy to private individuals.
- Plan for EV roadmap.

- Business model.
- Battery model and disposal strategies.
- Proposal for vehicle registration fee waive off.
- Proposal for free parking or designated parking for EV.
- Proposal to allow EV in no entry zones.
- Separate vehicle number plate for EV.
- Support to import spare parts with multiple vendors.
- Frequency of EV maintenance is low but there is plan for human resource training of EV mechanics.
- Liaising with Technical Training Institutes to train EV maintenance staff.
- Looking forward for collaboration with the university.

Meeting with Bhutan Power Corporation (BPC)

The following points were discussed during the three hours meeting.

- The ongoing EV project in Bhutan is executed by the Ministry of Information & Communication (MoIC).
- The senior official of BPC is a member of the EV project technical committee.
- BPC is not directly involved in implementing EV project.
- BPC is currently limiting its role to providing technical support and access to electricity for the charging stations to be installed in the current EV project.
- The cost of supply extensions to the new charging stations is in the scope of the
- EV project.
- While the BPC has plans to diversify its revenue sources, it does not have any immediate plan to venture into installing and operating the EVCS business.
- BPC is regularly monitoring the voltage/load profiles of the existing network to ensure that the system is able to accommodate charging stations coming up in future.

13.1.2 India

Meeting with EV Charging Station Developers

The following inputs were received at meeting with several EV charging station developers in India

- Power company, distribution utilities should consider EV charging business as a new vertical
- Charging infra will require more private investment
- Bigger PSUs have evinced interest and slowly entering charging infra business
- Private sector like Volttic, Fortum, some European companies have begun operating EV charging stations
- Going to be a big number game for EV charging by 2030
- On-the-ground expertise to set up EV charging for Indian companies still lacking

- Number of charging stations in the country is ~300-400. Major traction in Delhi
- The country is taking proactive steps to bring EV charging-friendly policies. Some charging guidelines still missing
- Lack of enough compatible cars in the country.
- Guidelines regarding minimum number of charging station installation is hindering business. MoP guidelines should be amended.
- The 2W and 3W which are the frontrunners of EV adoption are facing problems to charge their vehicles. AC chargers are slow and time-consuming and therefore, not making business sense for the stakeholder
- The major concern to set up an EV charging station are associated costs and finding a suitable location. This is hampering return on investment.
- The rent/ lease model of setting up EV stations is costly in Tier 1 cities like Mumbai or Delhi, where EV traction is high.
- Presently, the cost of charging is ~Rs. 10-11/ kWh, which is not viable for an EV buyer
- Adding location cost to the model, EV station is not viable. Location cost and cost of power to EV station should be at concessional rates for the time EV adoption do not scale up
- CAPEX cost is very high, costing ~26-30 lakhs now
- Adding new EV charging stations incurs huge costs to the party who is putting in CAPEX, therefore players are sceptical
- Expecting good growth numbers in B2B going forward
- With government presently not regulating charging costs, margins are low
- Going forward, margin will depend on location and station utilisations
- EV charging business is expected to be an attractive business 10 years from now
- The business case for EV charging will evolve only after 2022. Presently, India is in early market development stage
- Expecting a target of ~500 charging station in the next 4-5 years
- All players are intending to set up a few charging stations in major cities and along major highways
- EV charging is a long RoI business
- States need to be more accommodative. Delhi, NCR area, Maharashtra, Andhra Pradesh, Kerala, Tamil Nadu to be major key states
- Business is investment heavy in nature. Subsidies would be required from government.
- Different states have different EV tariffs. It should not be more than Rs. 5.5-6/ kWh, otherwise, margins will be hampered by station owners

- If utilisation is good, end use cost can be close to Rs. 9/ kWh excluding land costs. If station usage is less, it will be a burden on infra developing companies
- Lot of potential in the EV charging space. Private investments need to pick up.

Meeting with BSES Yamuna Power Limited (BYPL)

The following inputs were received when we had discussions with officials of BYPL including head of sustainability and Manager (EV Projects) at BYPL.

- The utility is following the EV charging space closely
- A lot of traction is expected, given the recent government interest
- Delhi is expected to be the epicentre for EV charging infrastructure development initially
- Station utilisation rates not expected to be strong in the initial years for EV charging to be a full-fledged business model
- Charging stations, when clubbed with other revenue streams, may be feasible. Commercial establishments or parties having excess land should come forward to be parties to the EV station business
- 2W and 3W to be predominantly converted to EVs in the initial phase
- Battery swapping is a good business proposition but the utility does not intend to enter into it
- As far as EV charging is concerned, the utility will not enter directly into charging business in the near term.
- It is in touch with interested parties who intend to set up charging stations in its licensee area
- The utility is expanding its team of officials who will enable more charging station development through business development, licensing and metering

13.1.3 Pakistan

Several meetings were held with different stakeholders such as IESCO, BMW Dealership (Islamabad), Ministry of Climate Change, National Electric Power Regulatory Authority (NEPRA), and academic institutions. The discussions were held with different levels of officials, depending on the required information. Summary of discussions with different stakeholders is explained below:

Meeting with IESCO fficials

The highest number of meetings were held with officials of IESCO, especially with the planning department. Planning department was very cooperative in discussing and providing the required information and data for the analysis. They were engaged in different parts of the report were ever their input was required or consultation was required to formalize the agenda item. Summary of meetings is mentioned below:

- Discussed different technical parameters, such as jurisdictions, sanctioned load, distribution transformers, power transformers, loading conditions of feeders, CAPEX planning, medium- and long-term plans etc. The planning department did not provide the raw data for analysis, but allowed to analyse their set of data points in the presence of their officials on their system.

- Technical team was involved in identifying the potential locations for the installation of public EV chargers. One of the parameters for potential locations was the availability of excess power on power transformer and feeder for that area.
- Technical team was involved in load forecasting over the period of ten years and assessing the impact of EV charging on the grid.
- Discussions regarding the organizational capacity and planning for future in terms of capacity development program.
- Discussion regarding the dedicated team and department to facilitate the adoption of EV's.

For the CAPEX planning and business model development the basic unit costs were taken from the CAPEX planning team. For the business model options, the meeting was held with the Project Director of Advance Metering Infrastructure. His valuable inputs were incorporated in developing the model. The officials of IESCO had some reservations and limitations in developing the business model as it was not clearly defined in the mandate of IESCO. The basic reservation was the availability of funds for the new initiative and the support of federal government required to facilitate the electric utility for this project.

Meeting with BMW

Two meetings were held with the officials of the dealership to get the insight of how their EV charging setup is working. Outcomes of the meeting are as follows:

- The EV charger was setup to promote their upcoming models, but the EV charger is not operation now.
- It was a dedicated BMW charger to facilitate users of BMW i-series owners.
- The charger was free to use for any BMW owner.
- There was no charging fee, and the cost of electricity consumed for charging was paid by the dealership to IESCO.
- For sales and roll out of EV's in Pakistan they feel that the time has come when people have started taking interest in plug-in hybrids and pure electric cars.
- They feel that government needs to be more supportive and incentivize the purchase of EV's. Separate regulatory reforms for import and local manufacturing are needed to speed up the adoption of EV's in Pakistan.

Meeting with Ministry of Climate Change

Only one unofficial meeting was held. At that time the ministry was preparing the draft of Pakistan's 1st EV policy so they were reluctant to share and information or talk about the issue.

Meeting with Academic Institutions

Had very limited conversation with the team who published the report on electric vehicles in Pakistan. Their academic research work was more focused on the power system modelling and impact of load due to public charging. Their research group was also in the initial phases and trying to address more issues in the field of e-mobility.

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