PROMOTION OF ELECTRIC VEHICLES ON THE ROADMAP FOR CLEAN ENERGY TRANSITION: AN ECONOMIC EVALUATION FOR PAKISTAN

Pakistan Institute of Development Economics

Syed Samim Affan
Registration No. PIDE2021FMPHILECO28

Supervisor

Dr. Shujaat Farooq

MPhil Economics

PIDE School of Economics

Pakistan Institute of Development Economics, Islamabad

2024

Pakistan Institute of Development Economics

Pakistan Institute of Development Economics, Islamabad

PIDE School of Economics

CERTIFICATE

This is to certify that this thesis entitled: **"Promotion of Electric Vehicles on The Roadmap for Clean Energy Transition: An Economic Evaluation for Pakistan"** submitted by **Mr. Syed Samim Affan** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Economics.

Supervisor: Dr. Shujaat Farooq Signature: ____________

External Examiner: Dr. Yasir Ahmed Signature: ____________

Head,
PIDE School of Economics: Dr. Iftikhar Ahmad Signature: ____________

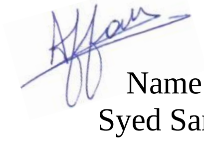
Author's Declaration

I **Syed Samim Affan** hereby state that my PhD thesis titled **Promotion Of Electric Vehicles On The Roadmap For Clean Energy Transition: An Economic Evaluation For Pakistan** is my own work and has not been submitted previously by me for taking any degree from Pakistan Institute of Development Economics or anywhere else in the country/world.

At any time if my statement is found to be incorrect even after my Graduation the university has the right to withdraw my M. Phil degree.

Date: 21-November-2024

Signature of Student



Name of Student

Syed Samim Affan

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to all those who contributed to the completion of this thesis.

First and foremost, I would like to thank my supervisor, Dr. Shujaat Farooq, for his invaluable guidance, support, and encouragement throughout this journey. His expertise and insights were crucial to the successful completion of this research. I am deeply grateful to my parents, family, and friends for their unwavering support and belief in me. Their constant encouragement and understanding made this endeavor possible.

I also wish to acknowledge the invaluable efforts of the academia and research think tanks, especially LUMS and SDPI, whose research and data on electric vehicles (EVs) were instrumental in shaping the foundational aspects of this study. The EV policy issued by the Ministry of Climate Change has been a pivotal effort in starting the journey to promote EVs in Pakistan. This policy has set the initial footing to initiate such debates and strategies to roll out EVs, possessing a significant impact on the country's clean energy transition.

Additionally, I acknowledge the National Transport Research Centre for their comprehensive data and analysis, which significantly enriched the transportation-related aspects of my research. I also recognize the International Energy Agency for their extensive reports and publications on clean energy and electric vehicles, which provided a crucial global perspective.

Furthermore, I appreciate the power sector entities, especially NTDC and NEPRA, for provision of data and reports on their websites that allowed for a detailed analysis of the electricity outlook in purview of the prospective EV transition in the country. Lastly, I acknowledge the support of various research literature that contributed to the depth and breadth of this thesis.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

BAU	Business as usual
BEV	Battery Electric Vehicle
CO_2	Carbon dioxide
CPEC	China-Pakistan Economic Corridor
EV	Electric Vehicle
FOREX	Foreign Exchange
GHG	Greenhouse Gas
GWh	Gigawatt hour or Million KWh
HDIP	Hydrocarbon Development Institute of Pakistan
HIES	Household Integrated Economic Surveys by PBS
IEA	International Energy Agency
ICE	Internal Combustion Engine
IGCEP	Indicative Generation Capacity Expansion Plan
KWh	Kilowatt-hour
KTOE	Thousand tons of oil equivalent
LVM	Latent variable model
MMTCO2Eq	Million Metric Tons of Carbon Dioxide Equivalents
MOCC	Ministry of Climate Change, Pakistan
MTOE	Million tons of oil equivalent
NEECA	National Energy Efficiency and Conservation Authority
NEP 2021	National Electricity Policy 2021
NEPRA	National Electric Power Regulatory Authority
NEVP 2019	National Electric Vehicle Policy 2019
NOx	Oxides of nitrogen
NTDC	National Transmission and Dispatch Company
NTRC	National Transport Research Center
OECD	Organization of Economic Co-operation and Development
PBS	Pakistan Bureau of Statistics
PHEV	Plug-in Hybrid Vehicle
PM2.5	Particulate Matters larger than 2.5 micrometer
RFO	Residual Furnace Oil
RLNG	Re-gasified Liquified Natural Gas
SOx	Oxides of Sulphur
TWh	Terawatt-hour or Billion KWh
VOCs	Volatile Organic Compounds

ABSTRACT

This piece of writing investigates the potential economic implications and benefits of integrating electric vehicles (EVs) into Pakistan's transportation sector. The study aims to analyze the economic impact of EV adoption in the context of the country's ongoing clean energy transition, considering factors such as energy consumption and value chain(s), energy burden, environmental benefits, and financial implications.

Utilizing data from various reliable sources, inter alia, National Transport Research Center (NTRC), Hydrocarbon Development Institute of Pakistan (HDIP), National Electric Power Regulatory Authority (NEPRA), National Transmission and Dispatch Company (NTDC), International Energy Agency (IEA) and Department of Energy of US, this research provides a comprehensive overview of the current state of EVs in Pakistan. The analysis includes a detailed examination of the EV policy issued by the Ministry of Climate Change, the National Electric Vehicle Policy 2019, highlighting its role in promoting EV adoption. The study further investigates the impacts on the aforementioned factors if the EV roll-out could have been planned earlier in resonance with the global trends.

This thesis aims to conduct a comprehensive evaluation of EV adoption as a critical catalyst for the clean energy transition. The study explores the factors influencing EV adoption, assess the environmental and economic impacts, and provides insights into policies and strategies that can promote a sustainable transition to cleaner energy sources. It employs policy analysis using OECD framework evaluation matrix and survey-based insights on the EV policy programming and implementation on the qualitative facet. Moreover, the Bass technology diffusion model is utilized to evaluate the envisaged growth figures. The computed growth figures are then used to calculate the economic impact and externalities in terms of energy outlook, consumer energy burden, emissions and foreign exchange drain on account of import reduction.

The findings of this study suggest that the adoption of EVs can significantly contribute to reducing GHG emissions, decreasing reliance on fossil fuels, and improving energy security in the long run. Furthermore, the economic analysis indicates potential cost savings for consumers in terms of energy burden, and positive effects on the national economy through reduced fuel imports. However, seldom positive dividends are realized in the short run attributed to the initial learning and research phase. It has been estimated that it would require at least 13 years to achieve 50 percent of the EV market share in total vehicle share. Had this happened earlier, today's grappling situation around current account management and energy crisis could have been well resourced. However, the advantageous aspect to this is that the energy mix in the electricity sector of Pakistan has recently entered into clean energy transition covenants that require massive adoption of renewables. This move, in conjunction with the accelerated roll-out of EVs, would yield more cleaner footprint on the environmental aspect.

This thesis concludes by providing policy recommendations to further enhance the adoption of EVs in Pakistan, emphasizing the need for supportive infrastructure, financial incentives, and public awareness campaigns. The insights from this research aim to guide policymakers, stakeholders, and industry leaders in making informed decisions to facilitate a successful clean energy transition for Pakistan.

Keywords: electric vehicles, EVs, energy transition, climate change, fuel imports, FOREX, energy burden, Pakistan

CHAPTER 1.

INTRODUCTION

Global communities and platforms are echoing debates on the adoption of electric vehicles (EVs) as a means to reduce greenhouse gas (GHG) emissions and contribute to the goal of mitigating climate change[1]. Governments in North America, Europe, and Asia have extensively implemented policies that try to provide incentives to EV technology, consumers and prospective buyers of EVs (Sheldon & Rubal, 2024). The efficacy of measures aimed at augmenting the market dominance of EVs has consistently been a topic of discourse in scholarly literature (Martins et al. 2023).

Pakistan has also instilled its stance on transition to clean mobility through facilitating dialogue [2] and rolling out the spectacular National Electric Vehicle Policy 2019 [3]. This policy has set forth a bold vision to step up the uptake of electric vehicles in the country while considering some key milestones, including (but not limited to) EV market development, gradually shifting the consumer preference to EVs through awareness and innovative incentive schemes, and localization of the EV value chain. However, as per an estimate done by Naveen (2024), the number of Battery EVs (also popularly known as BEVs) on road for Pakistan are just below 15,000 units[4], which is significantly lower than the India's and China's EV footprint of 2.8 million[5] and 16.1 million vehicles (IEA, 2023), respectively. These statistics clearly show that Pakistan has a long way to go. It is widely recognized that the significant obstacle to the widespread adoption of EVs is their higher acquisition cost in comparison to

[1] To quote some examples – Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles, Electric Vehicle Innovation Summit, Carbon Capture Technology Expo, EV Summit UK, EV Summit USA are some forums that have been establishing massive advocacy to accelerate EV deployment.

[2] There have been multiple symposiums, discussions, sessions and debates on the subject in the country which have been actively attended by the policymakers, regulators, relevant public sector entities, development finance institutions (DFIs), and academia. An example of one such event is 2nd Symposium on Battery Electric Vehicles in Pakistan: https://lums.edu.pk/news/lums-hosts-2nd-symposium-battery-electric-vehicles-pakistan.

[3] The National Electric Vehicle Policy 2019 (NEVP 2019) was approved by the Government in

[4] Also quoted by Asian Transport Outlook in Pakistan E-mobility Country Profile in 2024.

[5] https://www.autocarpro.in/analysis-sales/india-has-over-28-million-evs-on-its-roads-central-and-south-india-dominate-ev-ownership-116358

conventional vehicles. This is mostly due to the substantial research and development investment and fixed asset investment required by car manufacturers. In the context of a novel eco-friendly technology, obstacles also encompass consumer ignorance and limited consumer risk tolerance (Jaffe & Stavins, 1994), resulting in an ineffectual distribution of goods and services, sometimes referred to as a market failure in the field of economics. Therefore, implementing policy incentives is a logical approach to rectify the market (Harvey 2020, Hodge et al 2020, Lieven 2015). Policy incentives for EVs take into account both financial and non-financial incentives (Hardman et al 2018, Sierzchula et al 2014).

Predicting the adoption of EVs is heavily influenced by the availability of charging infrastructures. Similar conclusions were deduced by Sierzchula et al. (2014), and Netschert (2018) regarding the relationship between the charging stations (per capita) and the market share of EVs in an economy.

Furthermore, Wang et al. (2019) assert that as government regulations and policies concentrate on both consumers and automakers, they are essential in encouraging the sales of electric vehicles (EVs). These regulations frequently include setting goals for growing the number of EV adoptions, prohibiting the use of conventional fuels, and mandating the manufacture of EVs. Examples of this type of legislation are standards for low-carbon fuels, zero-emission vehicle mandates, and GHG limitations. Similarly, the global pioneer in EV industry, the Asian giant, China has also issued both supply side and demand side incentives and policies to foster the growth of EVs. The EV manufacturers are attracted through incentives for innovation, sales, customer satisfaction, and certain technical benchmarks. While the consumers get significant advantages through purchase subsidies, purchase tax exemptions, exemptions from vehicle and vessel taxes, tolls, parking fees, leniency in insurance fees and subsidized charging tariff (Zhang et al. 2024).

The total economics of EVs would need to be better than alternative options for EVs to gain traction in the private automobile market. This is because the current leading battery technology, lithium-ion (Li-ion), is still somewhat costly. Prior research has predominantly concentrated on the overall cost of batteries, whereas more recent studies have examined the incremental cost and its impact on determining the most cost-efficient battery size (He et al. 2019).

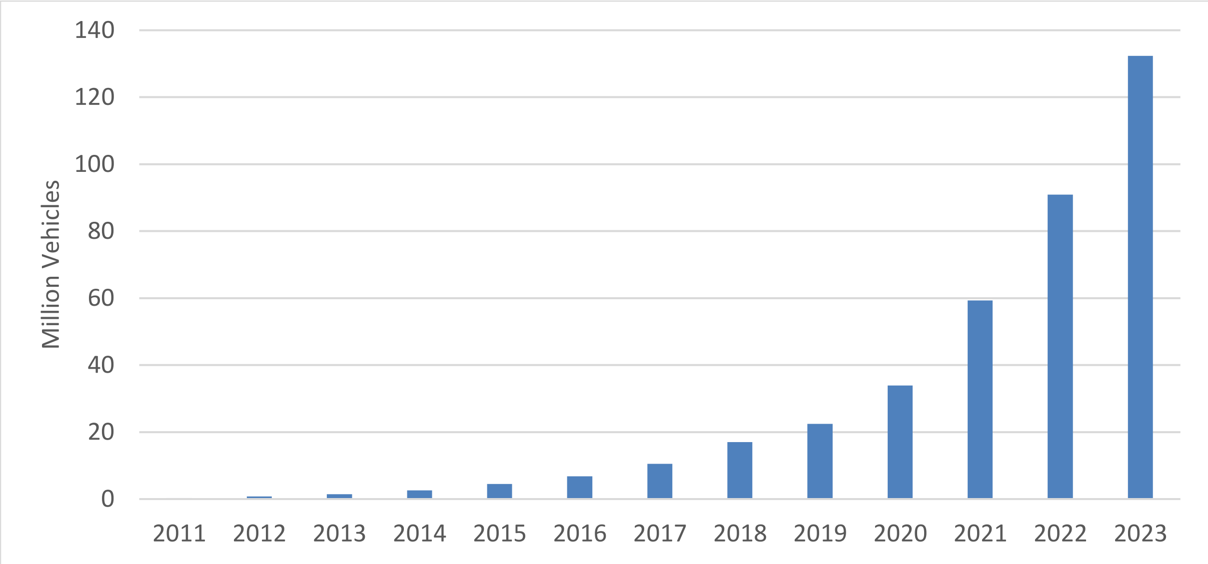


Figure 1. *Global electric car stock trends, 2011-2023*

Source: IEA analysis based on country submissions and data from ACEA, EAFO, EV Volumes and Marklines

The global urgency to mitigate climate change and reduce carbon footprints has led nations to reconsider their energy strategies, particularly in the transportation sector. This can be prominently observed through the growth rates of EV sales around the world. Figure 1 above, depicts the exponential adoptions of EVs across different economies majorly indicating the acceptability of the major economies to move at fast pace through the innovation and research phase of the technology adoption. As a developing country with challenging economic conditions and a rapidly growing population, Pakistan stands at a crucial juncture in its energy transition journey. This thesis aims to explore the pivotal role that EVs can play in this transformative process.

As we pen down this writing, the energy experts have been conclusively proposing specific time-of-use tariff measures to be offered to EV consumers to smoothen and shave of peaks in the power demand and hence managing power generation economically.

The clean energy transition for green mobility, furthermore as per Sierzchula et al. (2014), has been observed to be initially taken up by the higher income groups. EVs often come with a higher initial purchase price compared to traditional internal combustion engine vehicles, which leads to their adoption being skewed towards higher-income individuals who can afford the upfront costs. This is due in part to the higher purchase price of EVs, the ability to install home charging infrastructure, and less concern about the premium price in exchange for new technology or environmental benefits.

Although federal and state incentives, rebates, and tax credits are crucial for lower-income buyers to consider EVs, higher-income groups are more likely to benefit from these incentives due to their tax liability and ability to pay upfront costs even without the rebates. Accordingly, distribution of social welfare among the lower income segments would require further analysis, as to what targeted measures may be taken to steer the underlying transition for the under-privileged. This may include considering focus towards 2- and 3-wheelers and public transit systems, deploying a targeted and distinctive taxation regime, etc. It is pertinent to mention here that economies, majorly the developed ones, have opted to strategize the roll out of such incentives and schemes commencing from the higher income groups to ultimately spill towards the lower income segments (Harvey 2020).

According to the Electric Vehicle Outlook Report 2023 by International Energy Agency, China, the dominant force in the worldwide adoption of EVs, has experienced substantial environmental advantages as a result of the swift expansion in electric car purchases. As of the conclusion of 2022, the number of electric cars on Chinese roadways surpassed 13.8 million, resulting in a significant decrease in the country's GHG emissions. This enhancement has led to the substitution of a significant quantity of oil usage that would otherwise have been utilized by vehicles propelled by internal combustion engines (ICE). Based on the latest projections, the road transport sector in China is anticipated to experience its highest level of oil demand by around 2025. By 2030, the widespread use of EVs will lead to a decrease of almost 700 million tons of CO_2 equivalents.

According to the report, the adoption of EVs in Europe has made substantial advancements. In 2022, there were 2.7 million EVs sold, which represents a 15% increase compared to the previous year. The growth of this sector has been driven by stringent regulations on CO_2 pollution and advantageous policies implemented throughout the European Union. The development of the EV industry in Europe has led to a significant reduction in pollutants emitted by vehicle exhausts, thereby making a significant contribution to the region's climate objectives. In 2022, Norway and Sweden declared that electric cars accounted for 88% and 54% of new car sales, respectively. EV adoption is projected to persistently increase, driven by the EU's Fit for 55 packages [6], which aims to achieve a complete elimination of CO_2 emissions from new vehicles and vans by 2035. The growing use of EVs in Europe and China is playing a vital role in addressing climate change by decreasing reliance on fossil fuels and decreasing GHG emissions.

1.1. Problem Statement

Pakistan is facing significant challenges related to energy security and environmental sustainability. Moreover, the bulging deficit in the foreign exchange of the country is majorly led by the petroleum imports driven by the mobility related applications at large. At present, the transport sector constitutes approximately 31 percent of the total final energy consumption in the economy, primarily constituting of fossil fuel-based engines or popularly known as internal combustion engines (ICEs). This implies that almost one-third of the petroleum import bills have been incurred on account of the transport sector. In FY-2023 the petroleum products imported to meet the transport sector requirements posted a bill of approximately USD 9.35

[6] EU Fit for 55 refers to the EU's target of reducing GHG emissions by minimum 55% by 2030.

Billion out of total USD 17 Billion petroleum imports and USD 55 Billion total imports[7].

For Pakistan, the integration of EVs has the potential to support the country's transition to a clean energy system through creation of a buffer towards inflexibilities inherent with the technologies steering clean energy transition. Pakistan, being one of the most affected countries in terms of climate change, has a high socio-economic cost of carbon emissions. As per a conservative estimate assumed in the National Electric Vehicle Policy (2019) of Pakistan, for each metric ton of CO_2 equivalent emission the economy gets burdened with approximately USD 50. This would imply that just in 2021, the economy had to lose away around USD 2.5 Billion on account of socio-economic costs attributing to the transport sector emissions in Pakistan.

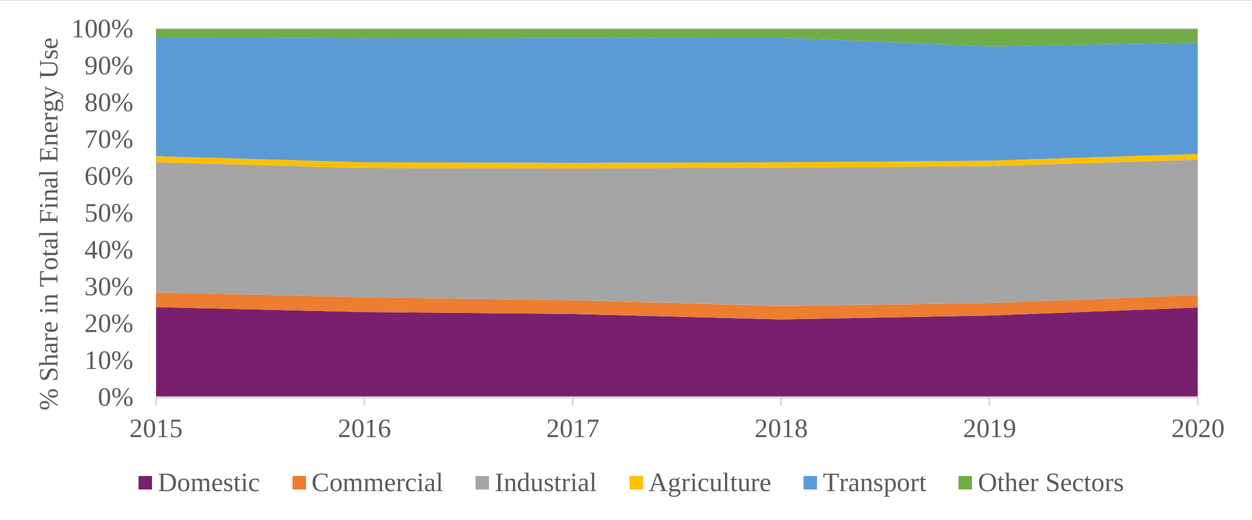


Figure 2. *Sector wise share of final energy use*

Source: Data taken from HDIP Energy Yearbook 2020

At the same time, the policymakers have ambitions to move towards massive deployment of renewable power sources in the coming years [8]. *Figure 3* below depicts the plan to integrate renewables, mainly comprising of wind and solar technologies across the grid in the coming years. However, the impact of EV integration on the clean energy transition in Pakistan is not well understood, and there is a need for a comprehensive economic and technical analysis to

[7] Data source External trade statistics, Pakistan Bureau of Statistics (2023)
[8] https://www.dawn.com/news/1827720 and also vide Indicative Generation Capacity Expansion Plan 2023 and 2024

evaluate the potential synergies and challenges.

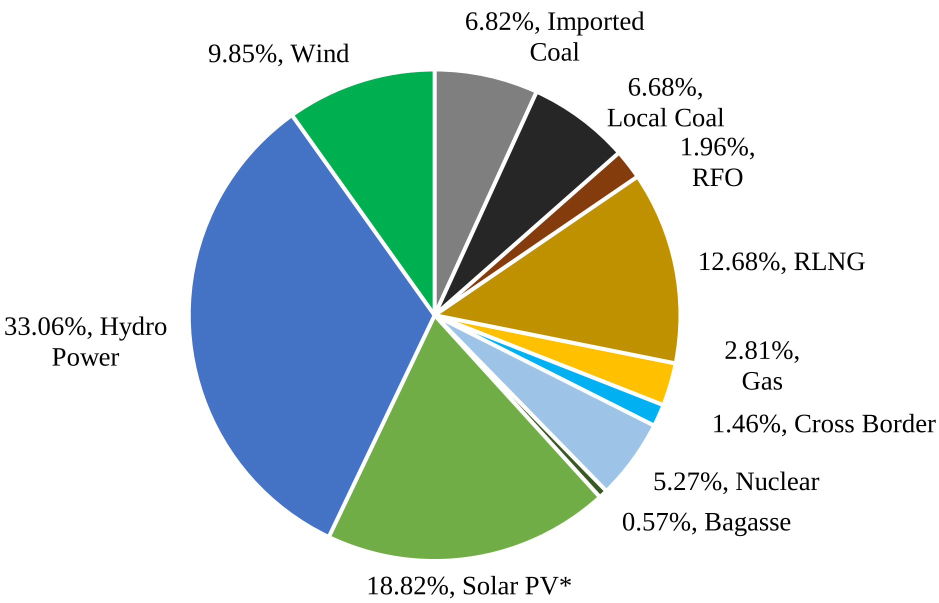


Figure 3. *Share of Planned Capacity Addition for Power Generation up to 2031*

Source: NEPRA Approved Indicative Generation Capacity Expansion Plan 2022-31 prepared by NTDCL

As per the statistics reported by National Transport Research Centre (NTRC), with approximately 25 million vehicles on the Pakistani roads with an annual average growth rate of approximately 9 percent mostly constituting of two-wheelers (77%), a great opportunity lies to transform the transportation outlook for the low- to middle-income households through promotion, expansion and electrification of two- and three-wheelers. Furthermore, per the stipulations of NEVP 2019, the stated income group may also be relieved through electrification of public transit solutions on excessively utilized routes. This shall not only support in reducing the carbon footprint and forex dependence but also enhance the social welfare of the lower income groups of the country.

As of 2021, total emissions of CO_2 in Pakistan were estimated to be 223.45 $MMTCO_2Eq$[9]. Energy related emissions (constituting 53% share in total CO_2 emissions) turn out to be around 118 $MMTCO_2Eq$[10]. Transport sector emissions were projected to be around 50.4

[9] https://ourworldindata.org/co2/country/pakistan.
[10] Chapter 7, Combating Climate Change, Ministry of Climate Change (https://mocc.gov.pk/SiteImage/Misc/files/Chapter-07.pdf)

$MMTCO_2Eq$[11], i.e., 43 percent share in energy-based emissions. This means that the carbon intensity of transport sector (30% share in final energy consumption) is significantly higher than other end-use energy applications / sectors.

Moreover, with Pakistan having an annual carbon footprint of approximately 800 $MMTCO_2Eq$ through emissions as reported in Updated Nationally Determined Contributions 2021 of Pakistan (GoP 2021), the policy aiming to increase the sales growth of EVs up to 30 percent by 2030 (NEVP 2019) implies a reduction in the emissions by up to 24-30 $MMTCO_2Eq$ (HDIP 2021) increasing on annual basis. Such intervention, henceforth, has multifold benefits for the economy and the environment.

The potential of EVs as a cornerstone of Pakistan's clean energy transition is immense. EVs offer a cleaner alternative to conventional ICE vehicles, promising significant reductions in GHG emissions and air pollutants. Moreover, the shift towards electric mobility aligns with Pakistan's broader commitments to the Paris Agreement and its national climate change policies (GoP 2021). Yet, the economic implications of this shift are multifaceted, encompassing aspects such as the initial investment in infrastructure, the impact on the automotive industry, job creation potential, and long-term savings in energy costs.

GoP (2019) issued a landmark policy, namely National Electric Vehicle Policy (NEVP) 2019, to give effect to and accelerate the deployment of disruptive mobility solutions. The long-awaited framework, once issued, invited a lot of debates and discussions in the corridors of the intellectuals to further pave the underlying directions. Having an inevitable future in the transport sector, EVs embark upon the new regime of energy landscape in terms of planning, economics, operations, consumer base and much more.

For Pakistan, the challenges stretch peculiarly differently on face of the fiscal consolidation,

[11] Greenhouse Gas Mitigation Options for Pakistan: Transport Sector, IISD & PITCO, CDKN (https://cdkn.org/sites/default/files/files/fact-sheet-Pakistan-Transport-sector-.pdf)

current account position, inflationary pressures, exchange rate patterns and many down-side socio-economic indicators that make the pathway towards EV adoption more cumbersome.

On the face of aforementioned circumstances, the Pakistan's optimistic EV Policy along with the ambition to deploy facilitating infrastructure may steer the adoption rate in certain income groups before others and pave a transit towards EV adoption provided that the policymakers and decision-making forums embrace the publicly declared covenants and implement them with letter and spirit.

The underlying EV Policy of Pakistan outlines achieving EV adoption journey through a 3-stage process:

1. Development of market and improving public awareness and literacy towards electric mobility, particularly in the zones of government incentives and subsidies,
2. Increasing the share of fuel import bill substitution through gradual and targeted penetration of EVs,
3. Indigenization of EV manufacturing lines; increasing the share of locally manufactured EVs in the Pakistani automobile market and moving towards exports of EVs.

Moving further towards the cost comparison analysis of the ICE-based vehicles and EVs in Pakistan, it may be comfortably stated that with sharply increasing learning rates of clean energy technologies, like batteries and other associated components, the automobile market is destined to observe significant drops in the EV prices that may further stimulate faster adoption and switching of vehicle owners towards EVs. Below, we present a general comparison of two vehicles (based on middle price range options) to depict the initial buying and operating costs of vehicles from both segments.

Table 1. *General Cost Comparison of ICE and EV vehicles*

Parameters	Unit	Toyota Corolla (ICE)	Hyundai IONIQ 6 (EV)
MSRP Price	PKR	6,424,589	10,409,250
Taxes/Duties/Registration	PKR	304,981	0
Freight	PKR	85,000	85,000
Estimated Annual Maintenance	PKR	50,000	5,000
Economy	PKR/km	28.00	5.55
Fuel Costs after 200,000km	PKR	5,600,000	1,109,348
Total Sunk Costs After 200,000km	PKR	12,024,589	11,518,598
Overall Savings after 200,000km	PKR	0	505,991

Source: www.pakwheels.com. Reference year: 2023

1.2. Research Objectives and Questions

This research mainly focuses its discussion to evaluate the viability of the EV policy in terms of its practicality, coherence, fostering clean energy transition, driving energy equity while achieving financial sustainability for the energy sector.

Accordingly, the thesis shall focus on three key aspects, (1) evaluation of the stated EV policy in light of its objectives, targets and key policy measures, (2) EV growth scenarios, (3) economic and environmental impacts of EVs for identified scenarios.

While the global shift towards EVs is gaining momentum as a critical element in the transition to clean energy Kumar & Alok (2020), its adoption in Pakistan faces unique challenges and opportunities (Naveed et al. 2021). The key research objectives for the underlying thesis are:

1. Evaluation of the policy framework of the country, particularly National Electric Vehicle Policy 2019,
2. Identification of various EV growth pathways by 2030 and economic impacts of such EV outlook.

To complement the aforementioned objectives, following research questions shall be addressed:

1. Is the provided EV policy effective enough to fulfill the desired goals and objectives in purview of the global perspectives?
2. Are the policy directives relevant, effective, efficient, coherent, impactful and sustainable?
3. Does the policy framework complement the requisite governance framework, i.e., mechanisms for monitoring, implementation and accountability?
4. Does the policy framework extend a suitable package of key targets, activities, timelines and budget?
5. What would be the EV outlook and market in Pakistan?
6. What impacts would the EV promulgation bestow on the economic, social and environmental fabric of Pakistan?
7. What will be the impact of EV promulgation on energy transition indicators, like clean energy footprint, emission footprint, energy burden, etc.?
8. What will be the impact of EV roll-out on the reduction in the foreign exchange of the country on account of reduction in petroleum demand?

1.3. Research Gap

The purpose of this study is to address the integration of the broader objectives of clean and sustainable energy transition with the widely and popularly discussed EV promulgation, and in general, clean mobility agenda in Pakistan. As we move down the road ahead towards modern times, we see growing advocacy and acceptance from the consumers to opt for EV. Accordingly, we also observe the research and literature for Pakistan to mainly focus on the associated areas of incentive designs, tariff regimes, consumer micro-economics, macroeconomic externalities in lieu of EV roll-out, etc. However, attention towards the prospects of integrating renewables and clean energy systems in the country with the EV growth is hardly found in the literature with Pakistan at glance.

Babar et al. (2020) and Shakeel (2022) discussed microeconomics, consumer viability analysis and EV purchasing decisions. The demand side opportunities to slash the carbon emissions were discussed, but the research overlooks supply side dividends that could have been reaped . Even when we see some hints towards the supply side clean energy transition, it has just been holistically discussed with no further deep diving into the matter.

Hodge et al. (2020) spoke about the policy frameworks supporting the EV adoption for Pakistan in particular while benchmarking through some successful regimes where EV adoption has witnessed commendable growth through an aided policy and regulatory setting. This, however, again overlooks the integration and coupling of renewables with the EVs, and accordingly enabling a net zero mobility cycle wherein the supply and demand may both help in reduction of carbon footprint.

This thesis shall focus on this aforementioned aspect of convoluting renewable energy penetration with EV adoption and narrow down on the assessment of the magnitude of renewables and clean energy that can be prospectively deployed to facilitate EVs in the country, and hence, cleaning the overall primary energy mix of the country.

1.4. Significance of Study

The underlying study holds significant importance for several reasons that contribute to the broader understanding of sustainable development and energy policy in Pakistan.

a) Environmental Impact

One of the most pressing issues of our time is the need to reduce GHG emissions to combat climate change. By analyzing the economic impact of EVs in Pakistan, this study provides crucial insights into how EV adoption can contribute to a reduction in emissions. This has direct implications for Pakistan’s commitments to international climate agreements and its national environmental policies.

b) Energy Security

Pakistan's significant dependence on imported fossil fuels presents a peril to its energy security and economic stability. This study examines the impact of transitioning to EVs on reducing dependency and enhancing energy security. Pakistan can reduce the risks linked to massive variability in global oil prices (affecting the prices of gasoline and diesel which are primary fuels for the ICE vehicles) and supply interruptions (either due to FOREX shortfall or geopolitical risks) by transitioning to domestically generated electricity. This shall be helpful for self-sustainable and clean mobility sector on various fronts, inter alia, cleaning the operational supply chain of EVs, reducing the burdening of FOREX due to EVs running on road and allowing the flexibility to the decision makers and regulators to insulate electricity prices, especially for EVs.

c) Economic Benefits

The research evaluates the prospective economic advantages of embracing EVs, encompassing financial savings for customers and enterprises, along with the promotion of technological advancement. The economic benefits can greatly contribute to the overall growth and progress of the nation.

d) Policy Guidance

This work serves as an evaluation for the policymakers. The review of the NEVP 2019, supported by a critical analysis, can provide guidance for the development of more efficient policies to encourage the adoption of EVs. It provides a framework with decision matrix to qualify and classify the economic consequences and advantages, which may be adopted to create incentives, subsidies, and infrastructure expenditures.

e) Public Awareness and Acceptance

Gaining a comprehensive understanding of the economic ramifications of EVs is of utmost importance in order to enhance public knowledge and foster widespread acceptance. This thesis emphasizes and endorses the advantages and challenges, thereby promoting establishment of well-informed potential consumer base that is in favor of EV adoption. This can expedite the shift towards more environment friendly mobility alternatives.

f) Contribution to Academic Research

This thesis adds to the expanding corpus of scholarly study on sustainable mobility and the shift towards clean energy. Through the provision of comprehensive and structured evaluation, it contributes to the already published literature and sets a potential starting point for forthcoming research in the underlying area.

At the outset, this analysis is important because it thoroughly investigates the economic, environmental, and social effects of EV adoption in Pakistan. The conclusions and findings it offers are potential recommendations and suggestions for the policymakers, industry stakeholders, and the general public in making informed decisions to transition more smoothly and effectively to renewable energy in the mobility sector.

1.5. Organization of Study

The thesis delves into qualitative and quantitative analysis and discussions. It firstly evaluates the EV policy based on the OECD framework evaluation matrix, stakeholders' survey and generalized assessment. Further down, it assumes three (3) growth scenarios; (1) Slow Growth or Business as usual (BAU), (2) EV Policy target based growth or NEVP2019 growth, and (3) Accelerated growth. These growth trends are superimposed on the Bass model (Becker et al. 2009), a technology diffusion curve, to evaluate the requisite composition of innovators and imitators to succeed in the respective growth scenario.

Furthermore, technical, environmental, economic and social assessment is carried out to evaluate the impacts of growth scenarios up to 2030. Moreover, a what-if analysis is also carried out with the same impact aspects to evaluate the dividends that could have been reaped, had we opted to fast-paced EV deployment strategy from 2015.

Accordingly, chapter 2 provides the literature review on the research carried out in the EV topics, mainly pertaining to global EV policy designs, EV growth forecasting models and socio-economic impacts of EV promulgation. Chapter 3 provides the data and methodology contours that have been adopted to emphasize the thesis research and associated findings. Chapter 4 delves into the policy analysis through the lens of structural, administrative and governance frames while asserting views from the stakeholders. In chapter 5, the economic assessment is performed on the EV growth scenarios and what-if scenario. Chapter 6 concludes the thesis through unleashing key policy recommendations and proposed way forward.

CHAPTER 2.

LITERATURE REVIEW

The integration of EVs into automotive sector has prompted significant attention from researchers and lawmakers globally, driven by the immediate need to address climate change, decrease GHG emissions, and improve energy security. Research has extensively analyzed the diverse outcomes of EV adoption, highlighting its potential to completely transform the energy industry and make substantial contributions to sustainable development. Numerous studies and research have concluded that EV penetration may bestow environmental advantages through various facets, like reduction in carbon dioxide emissions and other detrimental emissions as and when compared to conventional ICE based vehicles (Creutzig et al., 2015), (IEA, 2020), (IEA, 2023).

Gallagher and Muehlegger (2011) conducted research on the necessary fiscal mechanisms to encourage the adoption of EVs. The study investigated the significance of government subsidies, tax incentives, and regulatory measures in expediting the adoption of EVs in the market. Moreover, Lutsey and Nicholas (2019) have studied that recent developments in battery storage and charging infrastructure have supported in coping with the initial challenges of high investment costs and range anxiety issues.

The economic dividends extend beyond the environmental benefits, in terms of factors like energy burden, foreign exchange savings and employment creation (Chen et al., 2021, He et al., 2019). As Pakistan embarks on its transition to clean energy, it is essential for the policymakers and decision-makers to understand global trends and how they impact the local socio-economic context. This chapter explores the current knowledge base, offering a thorough examination of worldwide EV policy designs, models for predicting EV growth, and paradigms of the economic implications. This sets the foundation for the underlying analysis of Pakistan's plan for adopting EVs.

2.1. Global EV Policy Design

Research literature provides very insightful aspects of evaluating EV policies. Sheldon (2022) investigated the prospects of short- and long-term impacts of policy incentives on the EV adoption rates. It drilled down into benchmarking of various financial and non-financial incentives that have been applied and proven favorable outcomes to achieve successful promulgation of EVs.

Steen et al. (2015) outlined a broader perspective of multi-lens approach, wherein they delved into the aspects of policy coverage over elements, inter alia, value chain, development and deployment phases, stakeholders/agents involved, and tools of the government (legal, financial, communication/awareness and organization/governance). Lieven, T. (2015) set a unique approach of opting to evaluate various policies through choice-based conjoint analysis to evaluate consumer preferences and statistics in terms of age groups, gender, literacy rates, purchasing power parity, etc. The findings from the article evolve around policy measures that comprise of two monetary measures, two traffic regulations, and three infrastructure related edges that are extended to the EV users. It was proven that establishment of charging infrastructure was the largest contributor in promoting the EV purchase decision in developed economies. Whereas, in the developing economies, this measure has to be coupled with cash grants to witness EV adoption at desirable scale.

Moreover, OECD, (2021) has provided a generalized policy evaluation criteria (popularly known as DAC criteria [12]) that evolves around the facets of relevance, coherence, effectiveness, efficiency, impact, and sustainability. A general policy review as per the OECD guidelines may find these criteria principles as a suitable starting point to delve into the policy analysis and gap assessment. Dixit (2020) and Aijaz (2022) sketched a blueprint of the India's

[12] OECD Development Assistance Committee (DAC) has adopted a comprehensive set of parameters to evaluate policies, frameworks and strategic plans of the government which are popularly known as DAC criteria.

EV policies and strategic targets. Their writings provide oversight on the incentive regime and EV development stages planned and implemented by the Indian government. They discussed that India's product and theme specific Production Linked Incentive (PLI) scheme for the supply side has incentivized and stimulated the EV manufacturers in India to compete the global brands starting from Indian market. At the demand side, the tax breaks and discounts have supported the EV adoption, especially in the 2- and 3-wheeler segment.

Hardman et al. (2018) evaluated the impact of policies on EV sales. As per this report, approximately 50% of the global EV sales up to 2015 were stimulated by the incentive regimes offered by the respective jurisdictions. This included subsidies and tax cuts, obligations on the automobile manufacturers, monetary benefits for EV users like exemptions from use of road charges (tolls, parking, annual registrations, etc.), strong network of charging infrastructure to reduce range anxiety, and road access policies. Similar evaluations are also found in the work done by Hodge et al. (2020), wherein they have carried out a benchmarking study for Pakistan with some developed EV markets into picture. They discuss about the efficiency and effectiveness of demand and supply side incentives – both financial and non-financial – that have been applied in economies like Norway, China, United States, India, South Korea and ASEAN region.

In a global context a trajectory toward zero-emission transportation is established by more ambitious policymaking. The implementation of zero-emission vehicle mandates and newly proposed GHG standards will guarantee a future surge in EV adoption (Global EV Outlook 2024, International Energy Agency). Some examples of such policy measures, their key targets are provided in the table below:

__Table 2.__ Examples of Global demand side EV policy initiatives

Sr. No	Jurisdiction	Details	EV Segment	EV targets
1.	California	New EV mandates issued in 2022-23. Metric: Share of total vehicle segment	Zero-emission heavy duty vehicles (HDVs) and passenger light duty vehicles (LDVs)	35% sales in 2026 100% in 2030
2.	European Union	CO_2 standards issued by European Commission approved in March 2023 Metric: Reduction in CO_2 emissions	New automobiles (base year: 2021) Vans (base year: 2021) Heavy duty vehicles (base year: 2019)	55% reduction by 2030 and 100% by 2035 50% by 2030 and 100% by 2035 45% by 2030 65% by 2035 90% by 2040
3.	United States	New greenhouse gas emission standards proposed by the United States Environmental Protection Agency in April 2023. Metric: Reduction in CO_2 emissions	Light and medium duty vehicles (base year 2026)	56% and 44% by 2032, respectively

Furthermore, global EV policies growingly aim to boost manufacturing, instead of only deployment. Governments are progressively unveiling policies aimed at bolstering EV supply chains, encompassing critical mineral supply chains and the fabrication of vehicles and batteries (Global EV Outlook 2024, International Energy Agency). A snapshot of some examples to highlight the policies that stimulated EV production are provided in the table below:

Table 3. *Examples of Global supply side EV policy initiatives*

Sr. No	Jurisdiction	Incentive / Policy tool	Details
1.	India	Production Linked Incentive Scheme on Advanced Chemistry Cell Battery Storage in 2021	Targets to enable cumulative production of 50 GWh of batteries indigenously by 2030 to integrate with locally manufactured EVs
2.	USA	Clean Vehicle Tax Credit in Inflation Reduction Act (IRA) in August 2022	Offers cash back incentives to EV manufacturers, i.e., up to USD 3750 is awarded if the battery satisfies the critical mineral criterion, and an additional USD3,750 is granted if the EV component criterion is met
3.	Europe	Net Zero Industry Act in March 2023 in alignment with Goals of European Battery Alliance	The EV manufacturers are mandated to indigenize 90% of their battery manufacturing to fulfill battery demand of the EU. Further, by 2030, this Act targets to achieve 550 GWH of combined manufacturing capability.

Similarly, on a separate note, China's EV policies have hugely impacted the EV sales in the country on a positive side. Whereas the removal of such policies in 2019 was followed by a sharp decline in the EV sales as well, indicating that incentives did play a significant role in clean energy vehicle adoption (Hodge et al. 2020). This also further embossed the need to carry predictable, consistent and gradual policy regime in terms of incentives and taxation towards new technologies, particularly EVs.

2.2. Salient Features of Pakistan's National Electric Vehicle Policy 2019

The National Electric Vehicle Policy (NEVP, 2019) of Pakistan, which was authorized in 2019, has the objective of tackling significant environmental and economic issues. Acknowledging that transportation is a major contributor to air pollution and GHG emissions, the policy aims to achieve a considerable decrease in these emissions by encouraging the widespread use of EVs. This policy and its underlying program is of utmost urgency for Pakistan, as it is among the top ten countries that are severely impacted by climate change. The policy presents a thorough strategy to shift the nation towards sustainable transportation, emphasizing the need to reduce the significant effects of climate change and improve public health by enhancing air quality.

The NEVP provides key policy targets for sales of EVs up to 2040. This approach has handed over to the public and private stakeholders a deadline to enable realization of the stipulated policy targets through market development, indigenization, infrastructure strengthening, consumer awareness, incentive regime, etc. The initial milestone is to stimulate market expansion and increase public awareness and acceptability by providing incentives and subsidies.

This initiative specifically aims to attract entrepreneurs interested in establishing EV-related sectors in Pakistan. The objective of the second phase is to replace the cost of importing petroleum by encouraging the domestic production and assembly of EVs. The ultimate stage, with a duration of five years, aims to accomplish substantial domestic acceptance and commence the exportation of EVs and their parts, capitalizing on the native expertise in research and production.

In order to promote the use of EVs, the policy implements several financial incentives and regulatory measures. These initiatives include discontinuation of additional taxes and sales tax on imported EVs, reduction in federal excise duty (FED), and further incentives through tax cuts for domestically manufactured EVs. Furthermore, the policy envisages incentives for the establishment of EV manufacturing lines and the development of a robust charging infrastructure. There is a strong will in the policy to encourage investments towards charging infrastructures. The primary emphasis is on the installation of energy-efficient DC fast chargers in major urban cities and beside major motorways.

The NEVP is expected to yield significant economic and environmental advantages. From an external trade perspective, the underlying initiative aims to significantly reduce Pakistan's dependence on bulging imported fuels. From an ecological standpoint, the envisioned growth of EVs shall substantially decrease the emission of GHGs and other detrimental air pollutants of the country, as a major chunk comes from the transport sector. This will, accordingly, ensure a healthy life of the people along with reducing the public health costs.

The NEVP 2019 provides a comprehensive framework for Pakistan to transition to clean mobility, with a focus on environmental preservation and economic development. The effectiveness of the policy depends on the efficient implementation and collaboration of various stakeholders, including public and private sector, and international agencies. The NEVP aims to establish a conducive atmosphere for the integration of EVs to encourage a greener, more sustainable, and economically resilient future for Pakistan.

2.3. EV Growth forecasting models

The growth and market footprint of EVs, pursuant to the designed policy framework, may be well read through vast readings particularly in the Global North, wherein EV promulgation has become quite mature. Accordingly, Segal (1995) utilized conjoint analysis to evaluate consumer preferences in contributing towards EV adoption. Segal (1995) considered price trends for alternative fuel and associated vehicles, relative preferences among vehicle attributes and income group classification to carry out the analysis of different EVs and its user base. This approach assigns levels to each attribute, creates sets of choices, utilizes survey-based approaches in this case stated preference surveys, analyses data using discrete choice probabilistic model, estimates market preferences, product demand, and price elasticities and accordingly recommends preferred EV market development strategy. The results drawn from the research indicate that there were six aspects that determined the consumer preference to opt for EV, which included buying and operational cost, range anxiety, multiple vehicle ownership, commuting behavior, income, and age.

Becker et al. (2009) used Bass model to forecast EV growth in United States by 2030. The paper advocated that the Bass model is highly suitable for estimating the adoption rates of electric automobiles due to its effectiveness in predicting the acceptance of products in the pre-production stage and its ability to consider network effects. Glerum et al. (2014) in their research for forecasting of EVs proposed conducting survey based on stated preferences and integrating the inputs into discrete-choice model. The discrete-choice model used in the research is a combination of latent variable model (LVM) and logit model. LVM creates segmentation among the respondents based on socio-economic characteristics and logit model utilizes attitude, socio-economic attributes and vehicle attributes to arrive at respondent's vehicle choice. This approach lacked the broader long-term perspective of novel technology diffusion. In terms of laying down a rich perspective over the potential methodologies to forecast new technologies, Wu & Chen (2022) provided comprehensive set of approaches adopted in research literature. This research primarily classified the methods in two sets, to predict future quantities of new technologies, such as EVs and their charging infrastructure, which are statistical and machine learning approaches. Statistical approaches included time series analysis, grey theory, autoregressive integral moving average model, exponential smoothing method, Monte Carlo simulation method, and Kalman filtering. The challenge faced in these approaches was that unpredictability of individual behavior significantly impacted the precision and robustness of the predicted outcomes. Therefore, the other approach, i.e., machine learning technique, proved to be effective in predicting future outcomes. The research, moreover, selected (as the most suitable approach) principle component analysis (PCA) and general regression neural network (GRNN) to predict EV growth across the globe with China in particular limelight. It further delved into measures to economize energy dispatch of electricity grid and improve the operational efficiency of EV charging patterns. However, one of the major backdrops of the underlying research is that it undermined the long-term outlook and government intervention levers like political and economic policies from its findings and analysis. Also, this approach lacked the basic parameters of technology diffusion theory.

A multi-model analysis has been conducted by Kumar et al. (2022), considering the world economies, to justify the appropriateness of various approaches in diffusion modelling. The research utilized Bass, Generalized Bass, Logistic, and Gompertz diffusion models, which according to the literature, have been tested and trialed across various value chains, sectors, technologies and products. It further concluded that the robustness and fitting of Bass model outperforms the other models for forecasting purpose.

Similar instances of utilization of technology diffusion models, like Bass model, have been found in the literature for multifarious technologies. To name a few, Barkoczi et al. (2015) utilized the Bass model to evaluate the adoption of mobile phones in young consumers over the period of next 15 years, Nam & Min (2008) focused on the adoption of internet broadband using the Bass model, and Sillup (1992) also utilized Bass model to forecast new medical technologies adopted by the consumers.

2.4. EV roll-out Economic Impact Assessment

The economic impact assessment for the roll out of EVs include multiple factors. This section explores specific aspects that have been discussed in the literature, providing an holistic overview of the economic dividends associated with the EV adoption.

1. **Overall energy savings:** Net energy demand may be significantly reduced through transitioning from conventional fuels (gasoline, diesel and CNG) to EVs. Netschert (2018) carried out a cost-benefit analysis, evaluating the expenses associated with conventional petroleum fuel sources and electricity. The results indicate that EVs have the potential to greatly decrease the total amount of energy in the overall primary energy mix of the economy. By replacing costly imported fuels with domestically generated electricity, economies can attain significant financial savings as well, so this initiative brings not only economic stability but also consumer welfare. Moreover, Zhebin et al. (2018) and Colin et al. (2019) have utilized power system production cost modelling tool. PLEXOS, to evaluate the capacity and energy mix of the power system fleet to fulfill the electricity demand through EVs.

   PLEXOS is a production cost model for the multi-horizon optimization of the capacity mix and energy mix of the power system (Colin et al. 2019). This tool is widely utilized across the globe, including Pakistan. As per the power sector's regulatory framework NEPRA (2022), NTDC-system operator is mandated to submit to NEPRA the long-term power system capacity expansion plan, namely Indicative Generation Capacity Expansion Plan (IGCEP). Accordingly, the power suppliers (currently DISCOs, and KE and CPPA on behalf of DISCOs) are mandated to submit to NEPRA the medium-term energy requirements, forecasted electricity prices and energy mix in the power acquisition plans. The results from this process inform the policymakers, regulators and utilities in making investment decisions to add capacity in the system, planning for the projected energy mix while addressing policy and socio-economic objectives and perform security constrained economic dispatch for the power generating assets.

2. **Electrification and infrastructure expansion:** The transition to EVs requires substantial enhancements to the electrical grid and the establishment of charging facilities. Noel et al. (2018) and Pg-Abas et al. (2019) emphasize the necessity of making strategic investments in electric power networks to effectively handle the growing demand caused by EVs. This includes taking rightful decisions while investing in clean energy technologies, enhancing the electricity grid capacity, ensuring reliable access to electricity, and integrating smart grid technologies.

3. **Impact on Tax Structure:** The transition from conventional fuels to electricity for transport sector shall unavoidably affect the tax revenue of the government. Netschert (2018) examined the transition of energy tax revenue while comparing petroleum levies (collected on ad valorem basis to the fuel price) and taxes associated with the electricity bills. Policymakers face both obstacles and possibilities in designing tax regimes that ensure fiscal balance and encourage the adoption of sustainable energy practices. The study utilizes distributional incidence analysis to evaluate the distributional effects of the tax among different income groups.

4. **Air quality and carbon emissions:** The adoption of EVs has the potential to greatly enhance air quality and decrease GHG emissions, making it one of the most notable advantages of EV adoption. Prud'homme and Koning (2012), Salisbury (2013), Pirmana et al. (2023), He et al. (2019), Chen et al. (2021), and Holland et al. (2015) have performed life-cycle cost analyses that compared the emissions and costs of ICE cars and EVs. These studies primarily examine significant pollutants such as carbon dioxide (CO_2), sulfur dioxide (SO2), nitrogen oxides (NOx), fine particulate matter (PM2.5), and volatile organic compounds (VOCs). It is concluded that EVs have the potential to significantly reduce harmful emissions. Furthermore, He et al. (2019) incorporated the effect of manufacturing lithium-ion batteries in the life-cycle assessment of EVs to further indicate the setback that EVs face on account of higher

life cycle emission at the point of new vehicle production. However, the research further takes note of the fact that operational CO_2 footprint of ICE vehicles outpaces EV initial CO_2 footprint within the first 20,000 kilometers keeping in view that the charging mix of the EV is led by a clean energy share of more than 55%. This is, further, endorsed by Benjamin (2023).

5. **Foreign exchange (FOREX):** The increase in adoption of EVs can greatly relieve the country's foreign exchange reserves by reducing the demand for petroleum imports. Salisbury (2013), Harvey (2020), and Arshad et al. (2021) evaluated the potential of EVs in reducing the foreign expenditures. They assumed that the EVs that replace the conventional internal combustion engine vehicles are being powered through the indigenous energy mix. It was found that this shift decreases dependence on the price volatility of the global petroleum products and improves energy security. In addition, the studies emphasize the potential for developing local production value chains for EVs and their associated components.

6. **Renewable energy integration:** EVs have a massive potential to enhance the integration of renewable clean energy sources into the electrical grid as the charging behavior of EVs can be manipulated by demand control tools like electricity tariff regime (e.g., time-of-use), demand side management (DSM) and demand response (DR) (IEA, 2023). Noel et al. (2018), Prud'homme and Koning (2012), and Arshad et al. (2021) investigate the feasibility of EVs to act as flexible loads that can be operated to manage with the fluctuations and intermittencies in renewable energy generation. By incorporating intelligent charging methods, such as time-of-use pricing and vehicle-to-grid (V2G) systems, it is possible to efficiently regulate the equilibrium between the availability of renewable power and use of electricity.

Adopting EVs can bolster energy independence of an economy by reducing the dependence on imported fuels. Noel et al. (2018), Chen et al. (2021), and Arshad et al. (2021) discussed the prospects of technologies like vehicle-to-grid (V2G) and solar rooftop deployments in enhancing the self-sufficiency of energy systems on consumer (or rather prosumer) scale, and hence reducing the energy burden. Countries can enhance their energy security and decrease their vulnerability to fluctuations in the global energy prices by utilizing distributed renewable energy sources that are readily accessible.

7. **Job creation:** The EV industry shall certainly impact the employment distribution across the industries and sectors. Arshad et al. (2021), Pg-Abas et al. (2019), Noel et al. (2018), and Salisbury (2013) have noted that the conventional automobile industry shall face a massive job displacement in lieu of EV growth. In fact, a larger growth may be observed in the EV industry. This would be on account of the distributed nature of the EV infrastructure and services. They, further, conclude the need to train and upskill the existing workforce and professionals in the existing automobile industry to cater for the labor demand in the EV industry.

8. **Maintenance cost:** The maintenance costs of EVs are lower as compared to vehicles powered by internal combustion engines. Prud'homme and Koning (2012) and Netschert (2018) have stated that EVs have leser rotating equipment, hence requiring no lubricants or regular lubricant related servicing. Consequently, the wear and tear and degradation of EV parts is very slow. Accordingly, keeping an EV proves to be considerably cheaper than conventional vehicles in this regard.

To summarize, the economic evaluation of the implementation of EVs demonstrate impacts on different facets. These include significant energy conservation, better air quality, less reliance on imported energy, improved integration of renewable energy sources, the creation of employment opportunities, reduced expenses for vehicle maintenance, and increased self-sufficiency in energy. The significance of strategic policy measures and investments in facilitating the transition to electric and green mobility cannot be overstated. It is crucial to ensure that the economic, environmental, and social benefits are fully achieved.

CHAPTER 3.

DATA AND METHODOLOGY

As per the best and dominant practices in the literature, EV growth analysis has been done using quantitative approach of technology diffusion, i.e., Bass model (Kumar et al. 2022). Moreover, the EV policy analysis has been performed using qualitative analyses comprising of OECD policy evaluation framework (OECD, 2021), analysis of general parameters, and a self-conducted survey.

3.1. Conceptual Framework

The underlying thesis explores the policy and economic aspects of the EV industry of Pakistan. It discusses the respective literature and research conducted across the globe, revealing best practices and benchmarks. This research, further, evaluates the socio-economic and environmental dividends that can be harnessed through the adoption of the EVs. It identifies the gaps and challenges faced by the energy and mobility sector and the policymakers, and potential measures and directions that can facilitate EV transition in the required momentum.

The analysis of NEVP 2019 is based on 3 activities that include general policy review based on a set of selected variables, OECD policy evaluation criteria and a self-conducted survey from the stakeholders including public and private sector participants. A commentary has been done keeping in view the above inputs to reflect the policy insights from analytical perspective. Further insights of the policy analysis have been discussed in Section 3.2.

The conceptual framework of the growth and impact analysis of EVs is illustrated in the block diagram below.

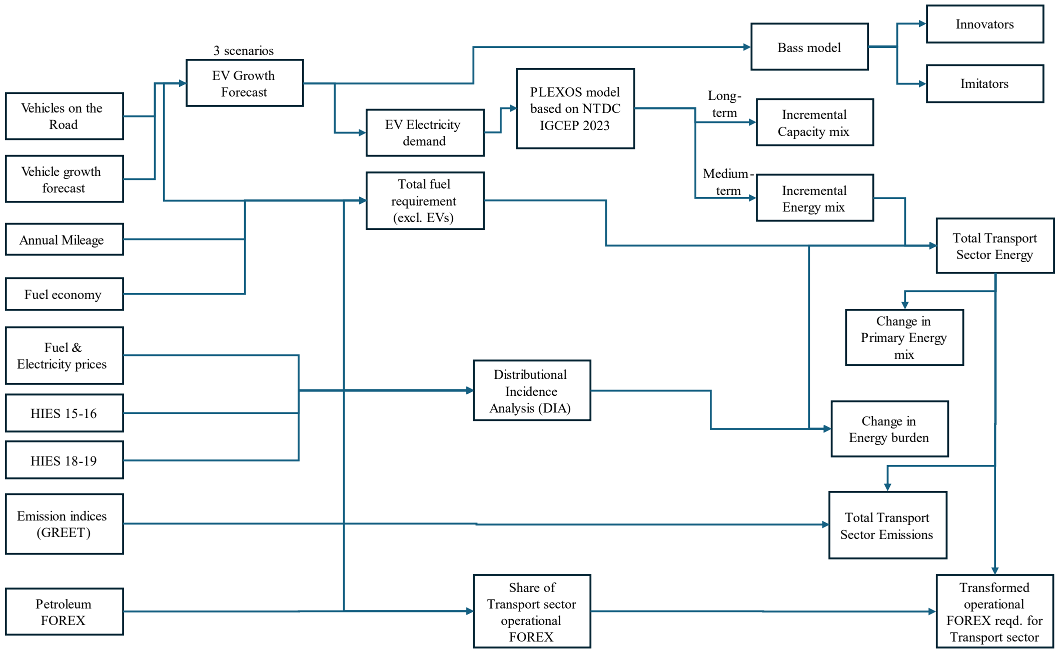


Figure 4. *Block illustration of the conceptual framework*

This thesis employs significant research results to examine the economic and environmental consequences of the deployment of EVs in Pakistan. The paradigm offers a thorough foundation for comprehending the potential external effects of Pakistan's shift towards electric mobility, encompassing economic incentives, environmental advantages, government initiatives, technology progress, and socio-economic issues.

3.2. Policy Analysis

Research strategy for EV policy review shall involve general fragmentation and analysis of the EV policy based on following three parameters and activities:

a. General observations

b. OECD policy evaluation framework

c. Self-conducted survey from the public and private sector stakeholders including relevant ministries, organizations and EV assemblers / manufacturers

3.2.1. General Observations on NEVP2019

The observations from the EV policy 2019 have been reflected in following aspects:

1. **Timeframe** – This aspect would discuss if the timelines in the underlying policy document were well designed.

2. **Responsibilities** – This aspect would seek the exclusivity and exhaustivity of the responsibilities in the EV roll-out project of the Government.

3. **Quantitative targets** – This aspect would discuss if the policy lays down strategic policy targets that can be measured to gauge the success of overall policy.

4. **Monitoring and implementation framework** – This aspect would evaluate if the policy framework sketched the mechanism to monitor and ensure implementation of the policy directive provided there within.

5. **Governance and accountability** – This aspect would evaluate if the policy provides mechanism to ensure accountability and escalation process in lieu of its implementation glitches around responsibilities and timelines.

6. **Budget** – This aspect would inspect if the policy document provides budgetary requirements or its discovery process to promulgate EVs as per stipulated targets.

3.2.2. OECD Policy Evaluation Framework

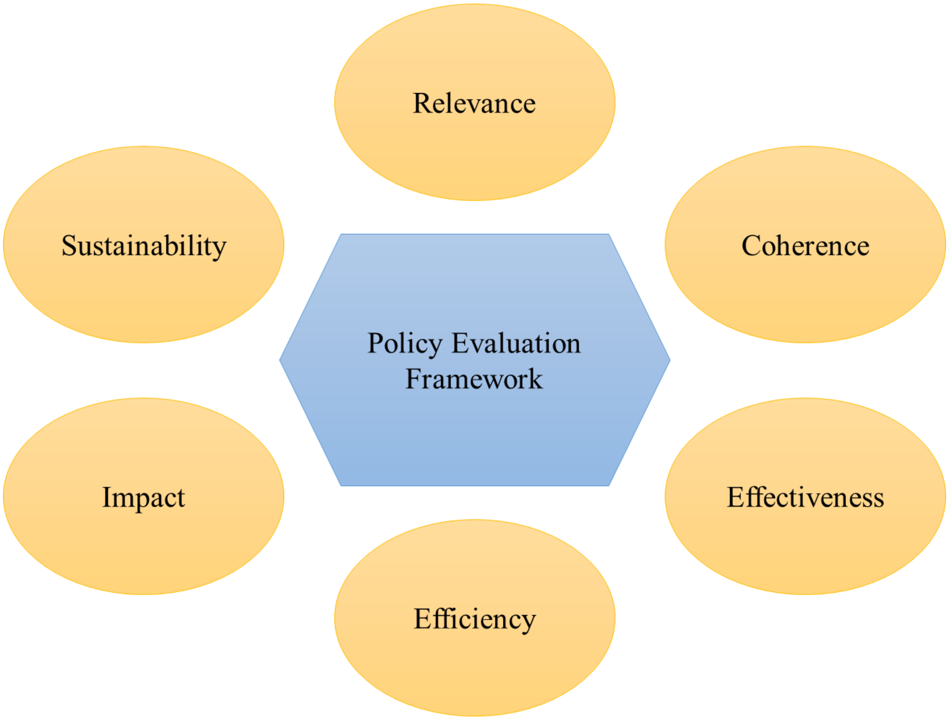


Figure 5. *Policy Evaluation Framework*

Source: OECD Policy Evaluation Framework – Applying Evaluation Criteria Thoughtfully (OECD, 2021)

Per the stipulations of the aforementioned framework (OECD, 2021), each of the aspects are discussed briefly below:

1. **Relevance:** When assessing the significance of a policy, it is crucial to examine how effectively it corresponds to the priorities and viewpoints of the target group, recipients, and stakeholders. In order to evaluate this, a number of inquiries can be posed. First and foremost, it is crucial to determine the present significance and extent of the program's goals. This involves assessing if the program's actions and outputs are in line with the main purpose and if they contribute to the successful achievement of the policy objectives.

2. **Coherence:** The extent to which additional interventions, particularly policies, enhance or diminish the efficacy of the intervention, and vice versa. This includes both internal coherence, which refers to the logical consistency inside a certain system or framework, and external

coherence, which relates to the alignment and compatibility with other aspects or settings.

Internal coherence refers to the harmonious and interconnected link between one intervention and other interventions conducted inside the same organization or government. It also involves verifying that the intervention aligns with the applicable international regulations and standards that the institution or government follows. External coherence refers to the alignment of the intervention with the interventions of other actors in the same setting, ensuring consistency. This encompasses the concepts of complementarity, harmonization, and coordination with other entities, as well as the degree to which the intervention provides additional value without duplicating efforts.

3. **Effectiveness:** Analyzing effectiveness requires considering the relative significance of the objectives or outcomes. The term efficacy is commonly used to quantify the overall degree to which an intervention has successfully accomplished or is anticipated to have significant and lasting consequences, in an efficient and consistent manner.

Effectiveness is a measure of how well an intervention is meeting its aims. It can offer valuable information on whether an intervention has achieved its desired outcomes, the methods used to achieve these outcomes, the key elements that influenced the process, and any unexpected consequences that may have occurred. Effectiveness focuses on the outcomes that can be directly attributed to a specific cause, whereas impact evaluates the broader and more significant changes that occur as a result.

4. **Efficiency:** The effectiveness of the intervention in attaining economical and prompt results. Economically pertains to the systematic conversion of diverse resources, including funds, expertise, natural resources, and time, into desired outcomes, consequences, and impacts, while reducing expenses in comparison to other feasible alternatives within the same circumstances. Timely delivery refers to the act of delivering anything within the originally planned period, or a timescale that has been appropriately modified to accommodate the

changing circumstances. This may involve evaluating the operational effectiveness (the extent to which the intervention was efficiently managed).

5. **Impact:** Impact refers to the overall importance and potentially profound consequences of the intervention. The objective is to determine the long-term and wide-ranging social, environmental, and economic impacts of the intervention that go beyond what is currently measured by the effectiveness criterion.

In addition to the immediate outcomes, this criterion aims to encompass the indirect, secondary, and potential effects of the intervention. It accomplishes this by analyzing the comprehensive and long-lasting modifications in systems or norms, as well as the possible impacts on individuals' welfare, human rights, gender equality, and the environment.

6. **Sustainability:** Sustainability encompasses an analysis of the financial, economic, social, environmental, and institutional capabilities of the systems required to maintain net advantages over a period of time. This entails the examination of resilience, hazards, and potential trade-offs. Depending on when the evaluation is conducted, it may involve analyzing the actual flow of net benefits or assessing the probability of net benefits persisting in the medium and long term.

3.2.3. Insights from Stakeholders

A comprehensive survey was designed and conducted from the relevant stakeholders, including public and private sector entities. The questionnaire was segregated into two sections, one for the public sector entities, especially relevant ministries and the second one for the private sector participants, mainly consisting of dealers, assemblers and manufacturers of EVs in Pakistan.

The questions were designed in four (4) specific themes, (i) Market development, (ii) Incentive design, (iii) Governance, and (iv) Indigenization. These questions delved into addressing the policy objectives as discussed earlier.

The construct of the surveys is provided in the table below:

Table 4. *Highlights from Survey questions*

Sr. No	Category	Theme	Respondent Type
1.	Market development	Level of success of the goals, objectives and targets in the NEVP 2019	Public Sector
2.	Incentive design	Roll-out and validity of the policy incentives	Public Sector
3.	Market development	Effectiveness and applicability of the legal and regulatory provisions to enable the EV policy stipulations	Public Sector
4.	Governance	Stakeholder engagement and effective delegation of roles / responsibilities	Public Sector
5.	Indigenization	Establishment of National Center for Electric Vehicles and Inter-Ministerial Committee on Electric Vehicles	Public Sector
6.	Governance	Clarity and relevant delegation of roles and responsibilities	Public Sector
7.	Governance	Mechanism to track, monitor, implement and set accountability for the delegated roles and responsibilities	Public Sector
8.	Market development	Success and *achieve-ability* of the National Electric Vehicle Policy 2019 (NEVP 2019) policy goals, objectives and targets	Private Sector
9.	Incentive design	Facilitative incentive regime that stimulates manufacturing capability	Private Sector
10.	Market development	Requisite improvements in the policy directives	Private Sector
11.	Indigenization	Indigenization pathways and prospectives	Private Sector
12.	Market development	Investor confidence and initial investment and research phases	Private Sector

3.3. EV Growth and Impact Analysis

3.3.1. EV Growth Scenarios

The EV growth shall be estimated based on initial ballpark assumptions which have been deduced from NEVP 2019 targets, i.e., 46% of share of EV sales in total vehicle sales (30% for 4-wheelers & trucks and 50% for 2/3-wheelers and buses), and thus named *NEVP2019* scenario. In contrast, the slow growth business-as-usual (*BAU*) scenario features a discount to the EV policy targets and targets to achieve ~2% of EV sales share in the total vehicle sales in 2030, whereas the accelerated growth (*Accelerated*) scenario assumes 70% share of EV sales in the total vehicle sales in 2030 (50% for 4-wheelers & trucks and 75% for 2/3-wheelers and buses). It was discussed earlier that Pakistan's current EV stock is below 15,000 units (Naveen, 2024), which translates to approximately 0.05% of the total vehicles on the road. In our baseline assumption (BAU scenario), we have assumed that EV share in sales (among the total vehicle sale) would start from 0.03% in 2024 and double each year following the technology diffusion theory (Jonathan & Kortum, 2001). For NEVP 2019 and Accelerated growth scenarios, S-curved based technology diffusion growth is applied on the 2030 targets for each scenario further projected up to 2040 (Glerum et al. 2014) and (Wu & Chen 2022),. The growth scenarios shall be superimposed on the Bass Model to arrive at the configuration and required properties of the underlying growth scenarios in terms of innovators and imitators.

Annual assumed forecasted EV sales growth is reflected in the table below.

Table 5. Share of EV Sales in total vehicle sales

Year Scenario	2024	2025	2026	2027	2028	2029	2030
BAU	0.02%	0.05%	0.12%	0.26%	0.49%	0.95%	1.92%
NEVP2019	1.37%	3.32%	6.74%	12.27%	19.21%	29.92%	48.58%
Accelerated	2.08%	5.03%	10.24%	18.67%	29.27%	45.61%	74.01%

Application of Bass Model

As per the findings of Kumar et al. (2022) regarding the performance of the diffusion model Bass model has been selected to evaluate the required innovator segment to achieve the requisite EV targets.

As discussed earlier, Becker et al. (2009) emphasized that the Bass model is highly suitable for estimating the adoption rates of EVs due to its effectiveness in predicting the acceptance of products in the pre-production stage and its ability to consider network effects. This research also provided an explanation of the model and utilized demographic and driving survey data to estimate the highest possible market penetrations for electric cars under various oil price scenarios along with the annual sales. The Bass model is a non-parametric conditional likelihood model that predicts the annual number of buyers for a new technology. It took into account three inputs: the maximum market size, a parameter representing the percentage of buyers whose purchasing decision is not influenced by others, and a parameter representing the likelihood of additional consumers adopting the technology based on the purchasing experience of others (imitators). The research suggested that this model is particularly suitable for estimating the level of market penetration for products that are influenced by network externalities as the case with the automobile industry. The inclusion of a third scaling parameter allows for the incorporation of the adoption behavior of consumers who postpone their purchases until the market has reached a certain size.

Bass model evaluates the innovators and imitators configuration required to adopt the above scenarios. It operates under the premise that the likelihood of making a purchase at any given time is directly proportional to the cumulative number of previous customers. The model assumes that the adoption rate follows an exponential growth pattern, reaching a maximum point and subsequently declining exponentially. The reason for this is the S-shaped growth curve, which takes into account important factors such as the innovation factor and imitation factor for new items along with the market size.

Innovators are individuals who embrace new ideas and technologies at an early stage, while imitators are those who observe and emulate the activities of innovators, influenced by both direct and indirect encounters. The model integrates the influence of both innovation and imitation factors on the diffusion of new products, making it widely popular in many study domains. The Bass model represents the adoption rate of a product or concept within a population at a specific period t, as represented by the following equation.

$$\frac{dF(t)}{dt} = [p + qF(t)][1 - F(t)] \quad (1)$$

In this context, F(t) denotes the cumulative distribution function that quantifies the proportion of the entire consumer base that has embraced the innovation by time t. Additionally, p represents the pace at which adoption occurs naturally, while q represents the rate at which adoption occurs by imitation. Innovators are unaffected by the time of adoption, whereas imitators rely on social engagement with these innovators. At first, only p is significant, but later, when the acceptance of innovation begins, q becomes the dominant factor in adoption. Ultimately, the rate of change decreases as the function F(t) approaches 1. Assuming K represents the market potential, the equation can be stated as follows:

$$F(t) = K\left[\frac{1 - e^{-(p+q)t}}{1 + (\frac{q}{p})e^{-(p+q)t}}\right] \quad (2)$$

This model shall help in understanding and targeting the requisite nature of consumers for EV adoption.

3.3.2. What-if Analysis

EV growth rates from the assumed Bass Model (discussed later) is applied from the previous years to land onto the impacts that could have been observed if the EV roll-out was planned earlier. The reference year of 2015 has been assumed in this regard. This is so because global EV penetration has been prominently witnessed after 2015 (IEA, 2023). The below figure from

Electric Vehicle Outlook Report 2023 of International Energy Agency substantiates the same.

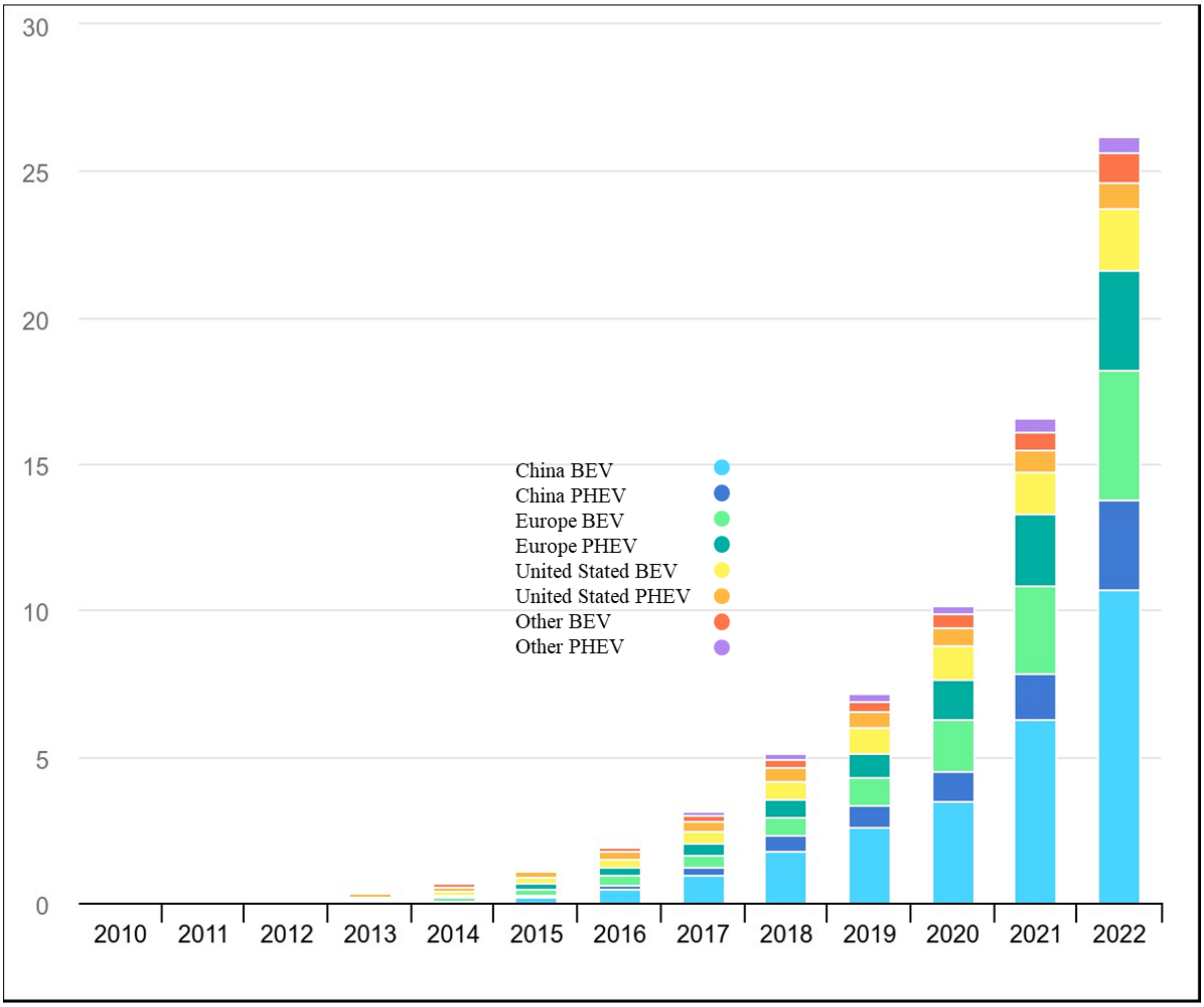


Figure 6. *Historical Global EV Footprint 2010-2022*

Source: Global Electric Vehicle Outlook 2023 Report by International Energy Agency

3.3.3. Impact Assessment

Economic and environmental impacts of EV promulgation shall be evaluated. Accordingly, following specific aspects shall be considered:

1. **Impact on electricity demand**; additional electricity demand created and prospects for renewable adoption – based on the future energy and capacity mix. The evaluation involves computation of block marginal energy mix due to additional EV demand using production cost modeling platform, PLEXOS model for Pakistan. As discussed earlier, this approach has been utilized in literature to evaluate the impact of EV demand growth on the energy mix of electricity generation (Zhebin et al. 2018 and Colin et al. 2019).

The model takes into account the future long- to medium-term investment decisions and dispatch to propose and optimize clean energy utilization for additional demand. Here, the demand being accounted for EVs, we observe the share of the additional energy in terms of thermal / conventional generation requirements and renewable generation requirements. This model optimizes the long-run marginal costs (LRMC) along with the short-run marginal costs (SRMC) in purview of the potential energy contracts within the planned generation fleet.

NEPRA approved NTDC's annual IGCEP is used for the underlying analysis as this plan forms the basis for future capacity investments and fuel procurements in the power sector of Pakistan. This model incorporates the 15-year lookahead to forecast most cost-effective (least cost) capacity additions in the power system.

2. **Displacement in overall energy balance**; facilitation in clean energy transition – As the share of EV grows, the composition of energy final consumption shall prospectively change. This may however not traverse to the primary energy supply of the country. Energy supply-demand balance has been built with EV scenarios in place to evaluate the change in energy portfolio of the country and all other variable factors ceteris-paribus [13]. This would mainly account for the transition from the conventional fuel system to centralized electricity system, which has a diverse time-variant energy mix.

3. **Emissions**; CO_2, SOx, NOx, PM2.5 and VOCs are the pollutants that have been computed to compare ICEs and EVs. Indices from Barrett et al. (2013) research findings have been deployed to evaluate the underlying impact factors. GREET tool, as utilized by Cornell (2017) has been deployed to evaluate the emission composition

[13] It is well known that the energy balance, primary energy outlook and final energy consumption would definitely evolve based on numerous factors and variables. As this is not the area of focus for this research, it has been overlooked and only the implications emanating from EV roll-out have been discussed.

of energy mix in electricity production of the country.

Moreover, the social cost of the CO_2 emissions has also been computed to reflect upon the implications on public health and environmental cost of air pollution in what-if scenario. The estimate for this has been assumed to be USD 50 per CO_2 metric ton of emission (NEVP, 2019)

4. **Change in energy burden**; Distributional incidence analysis has been carried out to evaluate the change in energy burden among different income groups of the households utilizing Household Integrated Economic Survey (HIES) 2015-16 and 2018-19 data. The microdata from the HIES surveys was used to segment the household expenses in 35 different categories, with energy categories fragmented and other expense buckets aggregated. The share of the energy expense in total expense is known as energy burden[14]. The shift from the conventional fuel system to electric fuel system shall make the households shift their energy expenses from gasoline, diesel, CNG and LPG to electricity.

   The energy burden is evaluated in a way that forecasted energy prices (forecasts for CNG, LPG, gasoline and diesel) and projected electricity tariffs are utilized to assess and compute the energy consumption. The energy consumption hints onto the distance driven by a certain household through a certain vehicle category. When the same utility in terms of distance is fulfilled by the EV of the same type (car or 2-/3-wheeler), the change in the energy bills is observed (a cumulative of electricity expenses, gas expenses and transport expenses) that reflects a shift in the energy burden on account of transition towards green mobility.

5. **Overall Operational FOREX savings**; Analysis has been conducted to evaluate the

[14] Low-Income Energy Affordability Data (LEAD) Tool documentation, Department of Energy, United States (https://www.energy.gov/)

annual savings in current account over the period of next six (6) years and in case of what-if analysis from 2015 to 2030, provided that the aforementioned scenarios are observed. The analysis takes into account the savings on account of petroleum imports. This activity observes the change in the import requirements if the transport sector demand gradually shift towards electricity. Reduction in conventional fuels means reduction in end-use demand for such fuels. However, the energy mix in the electricity production would play a role in accumulating the conventional fuel on the primary energy side. This is countered by the planned future clean energy projects, envisaged under power generation capacity expansion plans (IGCEP 2022 and IGCEP 2023, consecutively), which would mean that although electrification would require conventional imported fossil fuel, but it would be significantly reduced in next couple of years, progressively.

It is worth noting here that the FOREX requirements associated with the importing of EVs would also accrue. This may be coped through planning a greater share of meeting the local demand through local manufacturing at least starting from completely knocked down (CKD) units and moving further towards 100% indigenous manufacturing. Also, the sharply decreasing technology curve indicates that the EVs may achieve purchasing parity for lower-middle class customers in near future.

We had initially analyzed a general cost comparison of EV and ICE based vehicles (**Table 1**). This analysis indicated that up to 62% higher cost was required to buy an EV against the ICE vehicle of almost the same category. But is it worth mentioning that this cost may be recovered once the EV is driven up to 150,000-200,000 km, also saving on the petroleum imports that chronically drain the FOREX reserves.

CHAPTER 4.

ANALYSIS OF THE NATIONAL ELECTRIC VEHICLE POLICY 2019

The National Electric Vehicle Policy, issued in 2019 (NEVP 2019), lays down a comprehensive vision and strategy to promote the adoption of EVs in Pakistan. This policy seeks to tackle environmental and economic concerns by concentrating on enhancing market growth, improving public awareness, stimulating local manufacturing, and augmenting the export of EVs and their components. The objective of this thorough evaluation is to provide a meticulous study of the effectiveness of the policy, as well as identify areas for enhancement, by considering comments from stakeholders and critically examining the framework that underpins the policy.

The NEVP 2019 has established certain timelines and aims to achieve important milestones in the implementation of EV roll-out. The policy establishes two specific goal dates: 2030 and 2040. As per the target, it is expected that 30% of newly manufactured automobiles and trucks, as well as 50% of newly manufactured motorbikes, tricycles, and buses, will be powered by electricity by the year 2030. Moreover, it is envisaged that by year 2040, EVs would make up 90% of all new vehicle sales in every category. Given the economic realities of Pakistan and the past rates at which technology has been adopted in the transportation industry, these goals may appear overly ambitious. Implementing a progressive approach, in resonance with the behavior of the consumers towards new technologies in the past, may be more achievable and long-lasting.

This section has been segmented into three specific critical aspects to perform the review as per the stipulations provided in section 3.2. These three specific areas are:

a. Governance and administration

b. Structure

c. Views from the Stakeholder

4.1. Review of Governance and Administrative Framework of the EV Policy

The implementation of the tasks outlined in the NEVP 2019 involves several entities from different sectors and functions. The Ministry of Climate Change (MOCC) is primarily responsible for monitoring policy implementation, while the Ministry of Industries and Production (MOIP) focuses on promoting local manufacturing growth. The Ministry of Science and Technology (MOST) is primarily dedicated to research and development. Nevertheless, the assignment of duties and obligations is obviously deficient in terms of thoroughness and precision. This fact has become especially conspicuous after discussions with the respective officials from various ministries. Having a plan for operational coordination is crucial to ensure effective collaboration and synchronization among the different players involved. On the other hand, the absence of a comprehensive strategy for executing activities may impede the advancement towards key objectives. Hence, the policy needs to incorporate a thorough structure that precisely delineates distinct tasks, obligations, and methodologies for inter-agency collaboration to guarantee a smooth execution.

The NEVP 2019 sets ambitious goals, including achieving a 30% market share for EVs by 2030. Clear objectives have been set for the expansion of EVs in the markets for passenger cars, motorbikes, and commercial vehicles. These targets are divided based on the vehicle category. Furthermore, the policy aims to create a network of public charging stations, with the objective of setting up one charging station every three kilometers in urban areas and every thirty kilometers on highways. These strategic objectives should be regularly evaluated to ensure their relevance and achievability in light of technological advancements and market dynamics. This assessment is crucial in establishing the efficacy of the policy. Furthermore, the incorporation of intermediate milestones might be beneficial in terms of maintaining progress and providing regular evaluation points.

The NEVP 2019 has a deficiency in its framework for monitoring and implementing measures. The policy outlines the monitoring and implementation measures that will be carried out, providing limited information on the subject. While the establishment of an inter-ministerial body is mentioned, the precise duties and goals of this organization are not fully articulated. In order to ensure effective monitoring and implementation, it is crucial to establish a specialized technocratic institution that is accountable for completing thorough and sustained due diligence at every stage of the program's existence. The current policy fails to fully address the methods for regular monitoring, review, and change of policies based on performance measures. Given this inconsistency, there is a pressing need for a well-defined and robust framework to supervise the implementation process and ensure good governance. This aspect was also identified by the representatives of MOIP and NEECA.

The NEVP 2019 does not have sufficient measures in place for the governance and accountability systems specified in the agreement. The policy's efficacy in promoting ecologically sustainable transportation is compromised due to the absence of a well-defined escalation framework to address implementation challenges. The plan does not include provisions for implementing planning frameworks that may offer a systematic approach to governance and accountability. The policy should have included directions for periodic review and assessments to strengthen implementation and, hence, timely achievement of provided targets.

One such aspect in which the policy falls short of expectations is the financial visibility and budget related aspects for the implementation of NEVP 2019. The policy seems to completely overlook this aspect. Engaging with several stakeholders is essential for effectively identifying and obtaining the necessary financial resources. By adopting a multifaceted strategy involving collaboration between the public and private sectors, it would be feasible to offer a comprehensive financial plan that effectively supports the objectives of the policy. Through the exploration of innovative financing mechanisms, such as green bonds and public-private partnerships, it is possible to broaden the sources of funding and consequently decrease the financial risks involved. Moreover, the private sector representatives highlighted that the Government needs to plan with a firm and credible vision to take bold steps on the policy directives. This has been majorly neglected, as per the respondents, due to the fiscal crunch facing the Government. Accordingly, the financial planning for such schemes require approved budget and accounting prior to roll-out of such incentives.

4.2. Critical Review on the Structural Aspects of the EV Policy

The NEVP 2019 is extremely relevant as it aligns with the national goals of reducing fuel imports and promoting sustainable energy. To get initial acceptability from higher-income group, who are more inclined to adopt new technologies early on, the policy should be better integrated with wider energy objectives and focused initiatives. The adoption of new technologies by the higher income segments paces the learning rates of certain technology, forcing the producers to lower the margins along with bringing the technology costs downwards (Martin et al. 2012). Stakeholders, comprising both public and private sector organizations, have stressed the need for early adoption by higher-income groups in order to generate market momentum and attain long-term policy goals.

The current efficacy of EVs is being undermined by their high buying costs and the lack of government incentives. Stakeholders have asserted that providing financial incentives, tax benefits, and supplementary support measures is crucial for encouraging the use of EVs. In order to fulfill the environmental objectives of the policy, it is necessary to accelerate the implementation process and develop the required infrastructure and support structures. According to the results of a survey from relevant public organizations and private sector stakeholders, the success of EV industry is strongly related to Government will, consistent and predictable policy regime and continuous support along with the consumer-friendly incentives fostering EV growth. The incentives should be carefully crafted to address the unique challenges encountered by prospective EV customers.

Moreover, the program requires substantial alterations to improve its effectiveness, which is another crucial element. One significant obstacle is the absence of native manufacturing capabilities, along with an inadequate level of charging infrastructure. The government should adopt specific steps to successfully tackle these difficulties. Examples of such interventions include offering incentives for local manufacturing and investing in the development of a widespread and reliable charging infrastructure. If these steps are disregarded, the policy's capacity to promote the use of electric cars will remain limited. Stakeholders from both the public and private sectors have emphasized the significance of a strong charging infrastructure network to meet the anticipated increase in EV use. A developed infrastructure not only assists existing EV owners but also addresses range anxiety issue, therefore promoting new purchasers to take EV buying decisions.

The policy's vision on mitigating GHG emissions and enhancing air quality is in line with the objectives of public health and environmental preservation fundamentals. However, the limited adoption of EVs, against the policy targets, has hindered the complete realization of these expected benefits. To accomplish these environmental impact goals, it is essential to accelerate the adoption process and develop the required infrastructure and support mechanisms. Industry experts have stressed that major reductions in GHG emissions can only be accomplished by making a focused endeavor to significantly augment the number of EVs on the road. For the policymakers, one key aspect that attracts the promulgation of EVs is their substantial impact on environmental conservation, provided that this aspect of energy trilemma[15] remains a priority for the lawmakers. Therefore, it is crucial to efficiently communicate these benefits in order to gain widespread acknowledgement. It is pertinent to mention here that environmental sustainability resides well-below in the priority for the set of

[15] As per World Energy Council (WEC), Energy Trilemma consists of three key factors, namely, Energy Security, Energy Equity and Environmental Sustainability.

fundamentals that inform the decision matrix for the policymakers and consumers, alike. This is because of the equity related woes that have emerged in the face of excessively high energy prices.

The long-term success of the NEVP 2019 is heavily dependent on sustainability. The method seeks to facilitate sustainable economic expansion by cultivating energy autonomy and reducing dependence on imported fuels. To accomplish this goal, it is crucial to establish a conducive atmosphere by executing governmental programs that promote the transition to electric mobility. This includes not only fiscal incentives, but also regulatory support, public awareness initiatives, and the establishment of charging infrastructure. Based on insights from several stakeholders, it is evident that a sustainable transition will depend significantly on the government's consistent and long-lasting policy assistance. A consistent and predictable policy framework enhances the appeal of investments and instills trust in both customers and the industry.

It is essential to maintain consistency with other national policies and objectives in order to have a unified strategy for the adoption of electric cars and the shift towards sustainable energy. In order to instill its implementation, the NEVP 2019 must align with broader national energy and environmental vision and policies. Stakeholders from several sectors, including energy and transportation, have stressed the necessity of implementing integrated policy measures to enhance the efficacy of the NEVP 2019. By adopting an integrated strategy, it becomes possible to utilize the resources and infrastructure that already exist, resulting in a reduction of unnecessary duplication and an improvement in overall efficiency.

Conclusively, the following observations are noted for the underlying EV policy with OECD policy evaluation framework in purview.

1. **Relevance:** The NEVP 2019 instills its position as a landmark policy to support mobility transition for Pakistan. The policy provides direction to facilitate EV

promulgation on the Pakistani roads. However, it overlooks the outlook of the energy sector. The policy, further, sets forth some straightforward targets to be attained with regard to the EV sales in different vehicle segments. This, however, must be integrated with the national integrated energy plan of the Government. Moreover, the EV indigenization targets should be integrated with the national indigenization policies, plans and strategies to align with the overall vision of the Government. The tariff regime, similarly, should also be aligned with the Government fiscal consolidation with thorough findings as how will this affect the fiscal space in short and long-run

2. **Coherence:** The directives of the NEVP2019 seem to be coherent. Although, it is doubted that the incentive regime has been designed with the underlying targets in picture - which remains a research area. Moreover, we observe that although the policy is now in field for few years, most of the directives are still not applicable. This is so because there was an apparent absence of thorough stakeholder engagement during the policy formulation phase as also voiced by the private stakeholders during the self-conducted surveys.

   For the institutional facet of coherence, although the policy has been issued under the guardianship of Ministry of Climate Change, there lies no institutional or regulatory framework to support this on exclusive and exhaustive basis. An alternative case could have been that the policy document was drafted and issued by a consortium of ministries to allow the policy to be all-inclusive and agreed upon. From the integration perspective, the policy seems to remain alien to the cross-sectoral and cross-functional policies, plans, guidelines, regulatory frameworks, and codes. This could have been tackled through extensive stakeholder engagement and ensuring good governance practices during policy formulation phase.

3. **Effectiveness:** The policy targets seem to be behind the track. This may be mainly

attributed to the adverse and unpredicted economic conditions post-2019. Moreover, the policy directives seem to not attain their integration with cross-sectoral policies and frameworks. One such example of the same is the invalidity of the incentive regime, which has been overridden by various other regulations and policies.

This may also be observed on face of the institutional outset, wherein this diverse subject is still on the "round-abouts" of the legislation, planning, roles & responsibilities, and expectations. We do see minor developments around 2/3 wheelers. However, it is not in line with the policy targets. Further, as discussed above, the policy impact has merely been observed. However, as discussed further regarding the typical S-curve phenomena for technology diffusion, the impact in the initial years may not be significant. However, small positive impacts do indicate policy effectiveness.

4. **Efficiency:** The policy encapsulates key policy areas like objectives, incentive regime, high-level delegation of various cross-functional roles to various stakeholders. However, it overlooks some key features of a policy document like vision statement, institutionalization for policy monitoring and implementation, Government's priorities towards overall energy landscape, investments, etc.

   Moreover, some areas could have been improved like delegating the subsequent plan to provide for the target numbers and pathway while employing end-to-end approach, indigenization priorities and focus, establishment of a body to steer the policy directives, etc. The policy in overall periphery does take into account the challenges faced by the economy (and energy & transport sector in particular) and accordingly, provides the remedial actions but in its directives, it lacks the key niche that may foster and sail through the initial EV adoption phase during innovator's phase. Investments in electric mobility is also critically pinching.

   The world economies, at present, have paid significant focus on this aspect. Pakistan has a long ladder to climb on this contribution towards learning curve. Although bestowed with some of the best resources, in terms of labor, minerals, etc., it requires very focused effort to design an end-to-end pathway for sustainable EV roll-out that also enhances self-reliance on technology and energy resources.

Efficiency is also gauged in terms of timeliness of the policy framework. EV roll-out timing has been evaluated through the quantitative analysis. A simple comparison between what-if analysis and EV growth scenarios would reveal genuine insights into what could have been achieved in terms of energy mix, energy burden, FOREX drain and emissions. The two scenarios compare the 2030 snapshot, with EV program either started in 2015 or 2024.

5. **Impact:** The policy would provide a catalyst in the EV adoption phase through reduction in tariffs (custom duties). It further extends rebates and cut-offs in efforts that support indigenization of EV value chain. Moreover, the policy does indeed initiate a cross-sectoral coordination process that may lead to refinement of policy goals and objectives, preparedness of other sectors to promote and embrace the mobility transition and issue well-informed targets and responsibilities to implement the underlying transition on accelerated scale. Moreover, the policy intervention surely changed market expectations and economics. However, the misalignment between the policy, regulatory and institutional reforms has reduced the consumer confidence on the offered incentives. Once achieved, the policy intervention shall become a comparison for the consumers to opt for vehicle buying options while considering initial investments, operational costs, range anxiety, energy independence, charging behaviours, electricity tariff design and associated response, etc.

   The distribution of benefits across income groups shall be discriminative inherently in the technology diffusion process. This is so because the higher income groups shall be the first innovators to adopt the EVs. Furthermore, the lower income groups utilizing 2/3 wheelers could have been provided an added advantage through higher indirect subsidies, i.e., higher cut-offs in duties and taxes, as compared to 4 wheelers.

However, no additional incentive has been offered for 2/3 wheelers as compared to 4 wheelers.

Incentives to buses has the potential to traverse benefits to the lowest income segments. Here, again no further benefits as compared to 4 wheelers have been extended.

The policy should have accounted for all-inclusive offerings for different vehicle classes keeping in view the different income group beneficiaries in different vehicle segments. This could have included progressively increasing taxes over the conventional fuel systems, incentives for charging for different vehicle classes based on some verification process, etc. Public transit systems could be offered discounted electricity tariffs for charging public EV buses.

6. **Sustainability:** As the market moves towards EVs and once the maturity phase is achieved, the trend of EV adoption is poised to sustain. However, the credibility, predictability and consistency of the policy on the progressively growing trajectory of EV adoption along with the aided regulatory stipulations seems quite a challenging aspect. This comes into picture in lieu of policymakers' behavior with the unpredictable investment policies when it comes to fiscal and monetary stresses in the country.

   In terms of the environmental aspect of the sustainability that can be leveraged from this policy, it can be well-stated that although the policy has addressed somewhat conclusively on the energy demand parameter that is triggered through transport sector, but it overlooks the opportunity for cleaning the energy mix from the supply side through some directed measures.

4.3. A Glimpse on the Insights from the Stakeholders

As per the inputs from the private sector stakeholders, including manufacturers, assemblers and importers, the NEVP 2019 has not successfully achieved its policy goals or even achieved in instilling the envisaged direction due to inadequate government support, unpredictable policy incentives, exorbitant vehicle prices, insufficient public awareness and decreasing consumer confidence, as revealed by a survey conducted from the public and private sector stakeholders. Respondents stressed that in order to promote the acceptance and use of EVs, significant milestones need to be achieved in the areas of, inter alia, local manufacturing capabilities and charging infrastructure. Furthermore, it was asserted that Government guarantees and tailored interventions are necessary to address these problems and ensure the policy's effectiveness. The feedback collected from all stakeholders emphasizes the importance of addressing these critical issues in order to fully realize the potential of the policy. To foster a climate that promotes steady investment, stakeholders have consistently emphasized the need for the government to deliver clear and consistent policy signals.

In conclusion to the policy review on three discussed facets, although the NEVP 2019 sets forth a bold vision for Pakistan's shift towards electric mobility, the successful execution of this strategy necessitates substantial reforms. To successfully accomplish the ambitious objectives of the strategy and guarantee a sustainable shift towards electric mobility in Pakistan, it is imperative to tackle the issues related to exorbitant car expenses, taxation, infrastructure development, and government support. The policy review emphasizes the need for a holistic approach that integrates economic, environmental, and social considerations to create an environment conducive to widespread adoption of EVs. The objective of this comprehensive review was to hover through the importance of stakeholder engagement and the need for a well-supported strategic approach to achieve the policy objectives. To promote the widespread use of EVs and support Pakistan’s sustainable development objectives, the

NEVP 2019 can be strengthened by incorporating frameworks that can connect the implementation loop, enabling good governance and accountability, and delving into extensive stakeholder engagement.

CHAPTER 5.

EV GROWTH FORECAST AND ECONOMIC EVALUATION

In pursuance to the discussions in Section 3.3, this chapter shall delve into the prospective growth trends and evaluate the underlying economic dividends associated with each growth scenario. An initial base case (NEVP2019) was taken based on the EV Policy targets and extrapolated over the years. The other two scenarios, i.e., BAU and Accelerated scenarios were built around the EV policy targets, as discussed earlier.

The presumed growth numbers have been then superimposed upon the Bass technology diffusion model to evaluate the adjusted growth figures with the characterized market share and the levels of innovators and imitators in the technology promulgation process.

The economic evaluations, as discussed earlier, has been done on two facets, i.e., what-if analysis and future outlook analysis. In the what-if analysis, we dive into the proposition that if the EV roll-out would have been planned earlier in advance with the reference start year being 2015, what economic and energy transition dividends could have been yielded. Moving forward towards future outlook analysis, the economic evaluation is performed over the timelines outlined under that National Electric Vehicle Policy 2019 with two further scenarios that illustrate the economic outlook and energy landscape with slow growth and accelerated growth of EVs (as compared to EV policy targets).

5.1. EV Growth forecast using Technology Diffusion Theory and Bass Model

The applied EV growth follows S-curve trend per the stipulations of technology diffusion theory as developed by E.M. Rogers in 1962 (Leif, 2016). The theory segregates the technology adopters during different phases of its roll-out. The innovators (2-5% of the total consumer base) are pioneers who take massive risks to test new technologies. Certainly, these are people from higher-income groups. The innovators are followed by early adopters (10-

15% of the total consumer base) who take on the new technologies in the initial deployment phases but have a medium-sized risk appetite. Early adopters are followed by early and late majority, respectively (both 30-40% of the total consumer base each) and the last ones are laggards. The last three technology adopters are skeptical on change, tend to remain risk-free, and adopt to the trends only when technologies become very common in the society.

Bass model was employed to evaluate the EV promulgation in the country on account of stated growth scenarios. The results of the same are provided below:

Table 6. Share of EVs in Total Annual Vehicle Sales

	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
BAU	0.02%	0.05%	0.12%	0.26%	0.49%	0.95%	1.92%
NEVP 2019	1.37%	3.32%	6.74%	12.27%	19.21%	29.92%	48.58%
Accelerated	2.08%	5.03%	10.24%	18.67%	29.27%	45.61%	74.01%

Characteristics of each growth scenario are provided below:

Table 7. Attributes and Statistics of EV Growth Scenarios

	p	**q**	**R^2**	**MAPE**
BAU	0.0005%	67.01%	99.97%	0.39%
NEVP 2019	0.0458%	43.26%	96.58%	3.06%
Accelerated	0.0691%	43.62%	96.61%	3.10%

Where;

p represents the required innovators in the total vehicle buying population; as discussed earlier these are the pioneers (trend setters), who enable the market flow rom demand side

q represents the imitators which include early and late majority; usually the consumer segment that requires higher market inertia to take buying decisions for novel technologies

The findings reveal that EV growth policy has to significantly stress over the innovators in the prospective vehicle buyers to move towards EV buying decisions. This may be triggered through targeted policy decisions to simulate demand among the potential innovators. The findings further reveal that the naturally occurring phenomena of imitators may be overlooked as the requirement of such consumers shall be steered by the bold decisions of the innovators.

5.2. Economic impact assessment of What-if Scenario

Assuming the accelerated pathway scenario, if we had planned and succeeded in the promulgation of EVs starting from 2015, we could have reaped interesting and considerable EV footprint in the overall mobility sector of the economy. An assessment with the same accelerated growth model reveals that the share of EVs (in absolute terms) among the total vehicle fleet could have topped up to 63.2 percent against the projected 7.6 percent in the same growth conditions, as illustrated in the graph below. It was also observed from the what-if analysis that conventional fuel vehicles were being significantly replaced by EVs, signifying that consumer economics and parities could have been significantly tilted in favor of EVs.

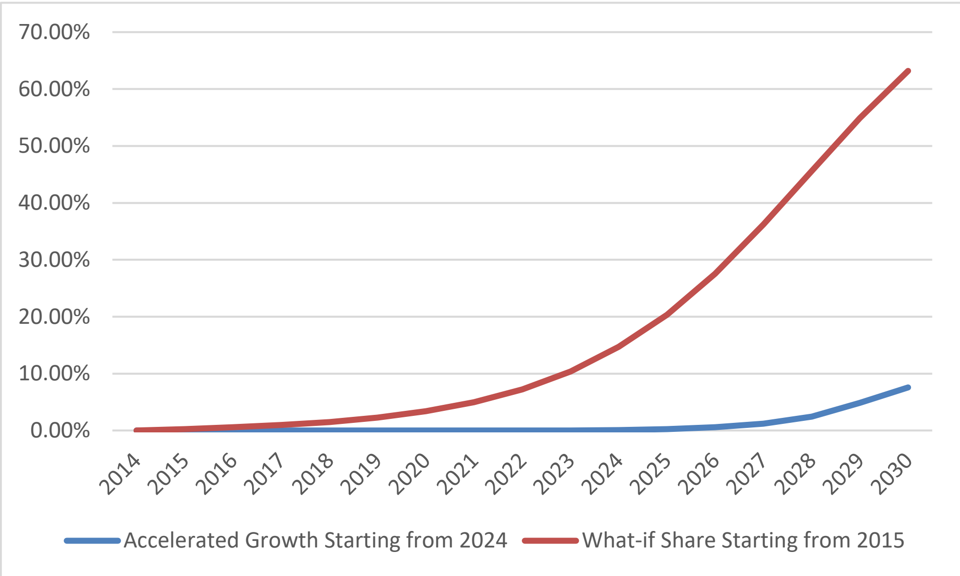


Figure 7. *Market Share of EVs in Total Vehicle Fleet of Pakistan (Actual & Forecasted*

This could have been so because we could have reached the rapid adoption phase of the disruptive technology adoption curve, wherein the market has gotten the confidence and maturity to accept newer technologies.

Economic impacts have been evaluated on the aforementioned parameters on two fronts, i.e., (1) what-if analysis, (2) implementation of EV deployments strategy post-2019 EV Policy.

5.2.1. Electricity Production Outlook and Demand

It has been analyzed that if the EV deployment strategy could have been placed on accelerated pathway commencing from 2015, we could have witnessed an additional electricity demand of 23.7 TWh (23.7 billion units) – i.e., approx. 12 percent share in total electricity demand. As per the block marginal energy mix, this could have enabled capacity additions of up to 5000MW of solar and wind resources (~4GW solar and 1GW wind), along with ~760MW of coal and 1GW of gas by 2030 (as illustrated in the graph in **Figure 9**). This means that the overall energy mix could have been improved by up to 10%, while also ensuring reliable and secure electricity production and delivery.

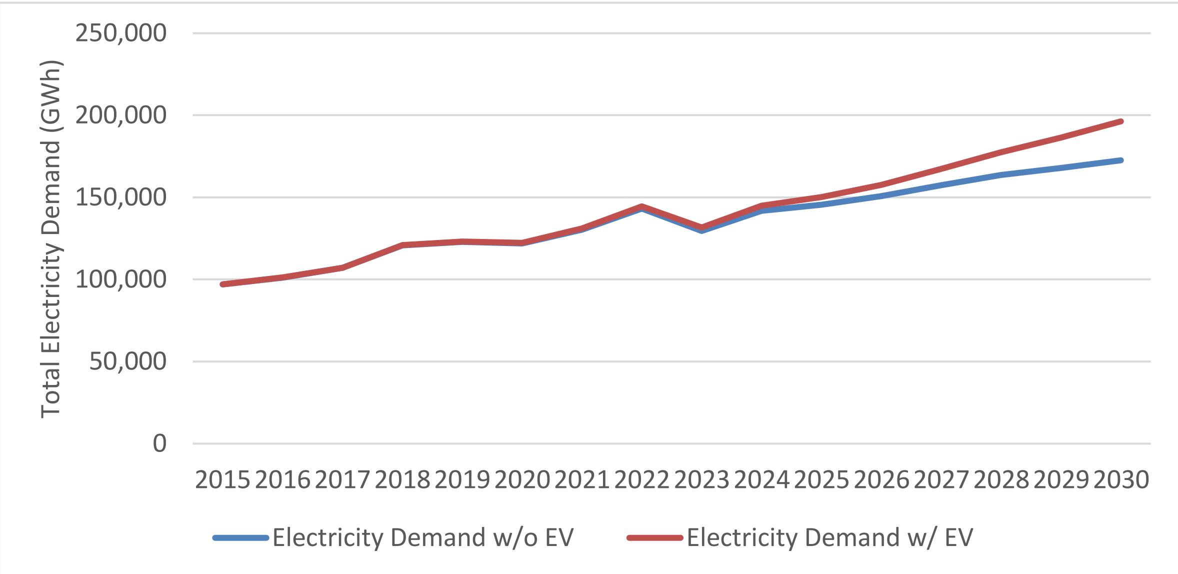


Figure 8. *Total Electricity Demand of Pakistan (with and without EVs)*

It is pertinent to mention that the associated coal and gas additions in the electricity fleet would be required due to the characteristic of renewables' variability and intermittency. This can be further enhanced through management of EV load in the system through dynamic pricing, also popularly known as demand response (DR), and ultimately reduction in thermal capacity investments may be avoided.

If we assume adequate DR measures are deployed, the need for gas and coal turbines may be slashed further and accordingly further investments towards the clean energy sources be expedited. Moreover, while considering the sharp increase in learning rates, the prices of battery systems may also achieve grid parity. This may allow provision of grid support services through cleaner energy sources already at par to hedge the shocks in the system.

These dynamics can certainly further improve the overall capacity and energy mix of the country.

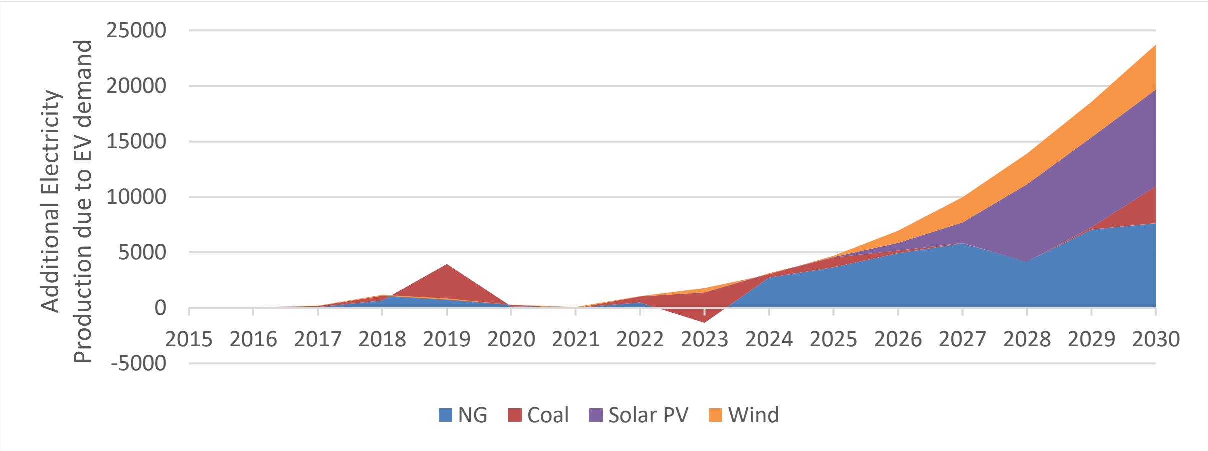


Figure 9. *Additional Electricity Production due to EV demand (GWh)*

Source: From internal analysis of block marginal electricity demand

If we analyze the EV demand through a different perspective; as this demand was supposed to be driven through policy tools, its behavior could also have been stimulated through well-designed tariff scheme – so as to deploy maximum solar and wind resources and reduce the thermal fleet additions. A major tariff regime for this could have been a combination of time-of-use tariff design and demand response-based dynamic pricing regime. However, we will not go into further details on this as this requires a separate in-depth analysis.

5.2.2. Energy Balance

The findings from the what-if analysis show that if the transition towards EVs would have been initiated by 2015, we could have saved almost 10.5 MTOE through efficiency gains. Not only this, but we could also have cut-off energy imports for the transport sector by almost half from as-is projected 25MTOE to 13MTOE in 2030 (with a growing trend onwards) and cumulatively 45MTOE from 2015 up to 2030. A depiction of overall projected energy efficiency gain that could have been harnessed is presented below.

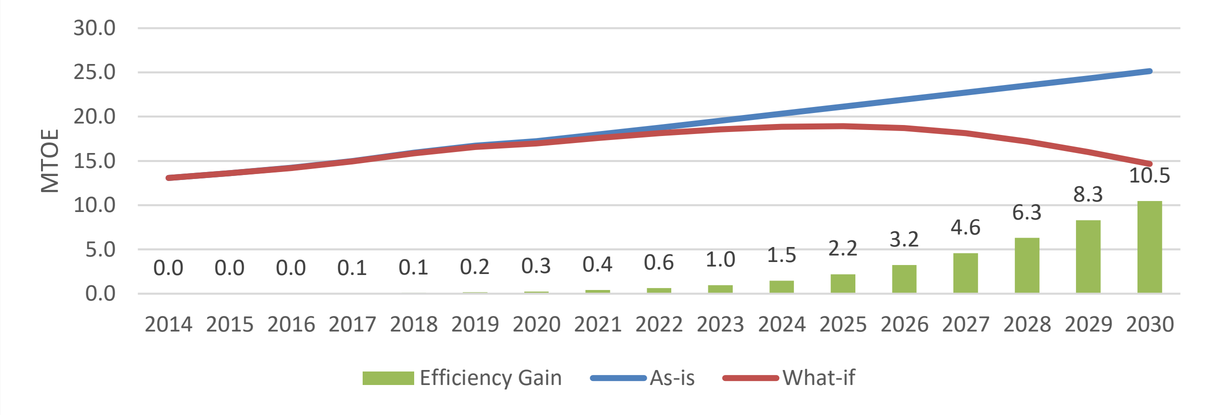


Figure 10. *Annual Energy Consumption of Transport Sector in As-is and What-if scenarios*

A glimpse of energy mix for the mobility sector in 2030 is provided below.

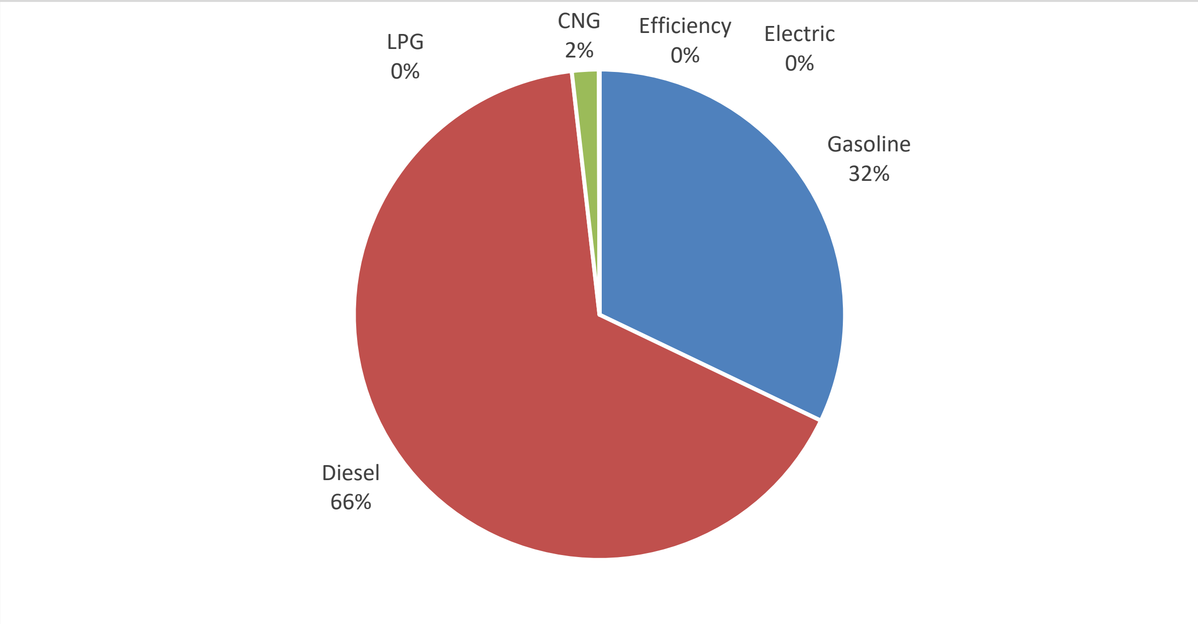


Figure 11..*As-is Energy Distribution of Mobility Sector by 2030*

Source: From internal analysis using 2021 base year data from HDIP (2021)

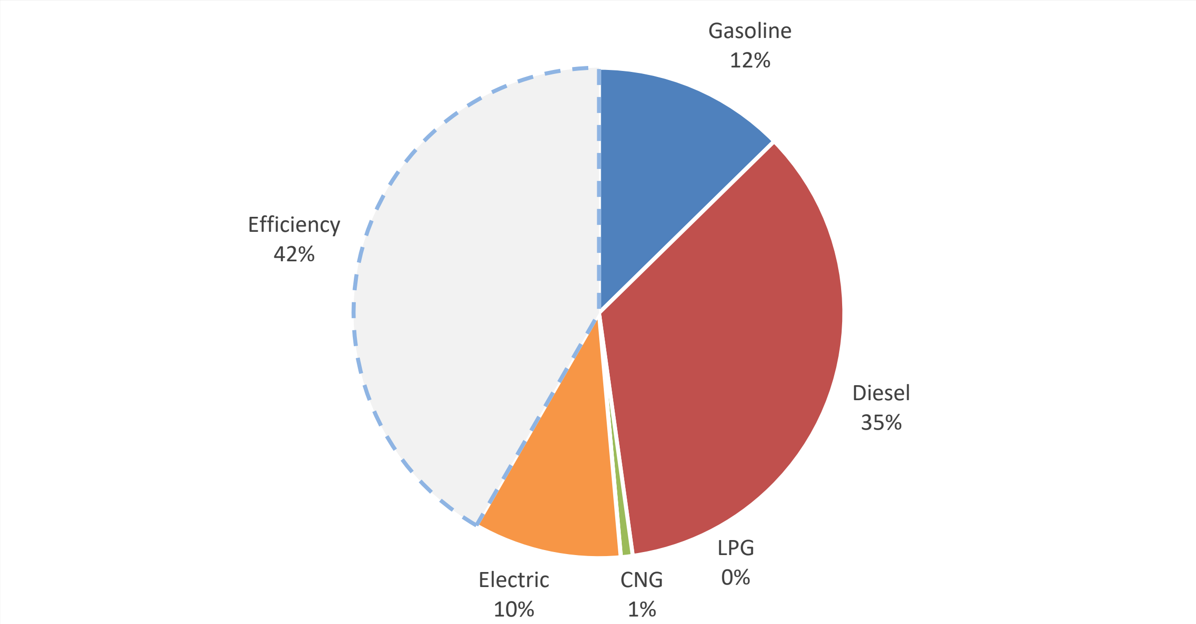


Figure 12. *What-if Energy Distribution of Mobility Sector by 2030*
Source: From internal analysis

5.2.3. Emissions

On the aspect of emissions, the following table shows a comprehensive outcome that could have been achieved provided we had facilitated accelerated adoption of EVs. The figures correspond to year 2030.

Table 8. A Comparison between As-is and What-if Scenarios

		Emission Scenarios	
Pollutant	**Units**	**As-is**	**What-if**
CO_2	Million tons	79	47
Sox	Tons	7,066	3,497
Nox	Tons	54,176	27,152
PM2.5	Tons	22,093	11,660
VOCs	Tons	36,978	18,062

The snapshot clearly shows that the reductions in emissions could have been cut into half in case of most of the pollutants. CO_2 emissions from the transport sector could have been reduced by 40 percent. As assumed earlier, if we employ the conservative estimates assumed under the EV policy framework for Pakistan, i.e., social cost of USD 50 per metric ton of carbon emissions, we could have saved the social cost of approx. USD 1.6 billion (in 2030 only) by initiating the EV roll-out plan by 2015 against the current projected social cost of

USD 3.95 billion in lieu of 79 million tons of CO_2 emissions.

5.2.4. Energy Burden

As the energy burden distribution was being evaluated from 2015 to 2030, the available Household Integrated Economic Surveys (HIES) by Pakistan Bureau of Statistics (PBS) were only for the years of 2015-16 and 2018-19. Accordingly, analyses were performed for the underlying microdata to gauge the change in the energy burden of the consumers. Interestingly, we find that the energy burden of the EV adopting consumer segment would have decreased by 3.9 percent in 2015-16 and by 4.4 percent in 2018-19. This signifies that the potential parity between the ICE and EV shifting on operational cost contour has widened.

Table 9. Energy Burden of Consumers on account of EV adoption

HIES	**National Average Energy Burden**		**Reduction in Energy Burden for Specific Consumers**		
	No EV Scenario	**EV Scenario**	**Car**	**Bike**	**Average**
2015-16	10.48%	8.67%	4.92%	2.32%	3.87%
2018-19	11.60%	9.00%	5.44%	3.15%	4.41%

Analysis performed using HIES 2015-16 and 2018-19

It is pertinent to mention here that the price volatility of petroleum products and electricity have a major impact towards hampering this transition as well. This may be dealt with a predictable price smoothening policy measure that may allow sustainable pricing of petroleum products and electricity.

Having said so, the energy burden is heavily reliant on the pricing strategy and taxation regime of the Government. In revenue-capped cost-plus pricing regime, where all the fuel and actual operational costs are passed on to the consumers, EV adoption has great potential to record savings for the consumers.

5.2.5. Foreign Exchange

In order to evaluate the FOREX impact, ex-refinery prices were used for petroleum products and for electricity usually at-source prices are considered with network losses topped up. The analysis reveals that a jump start towards accelerated EV deployment could have yielded a massive FOREX savings of up to as high as USD 29 Billion (cumulatively from 2015 to 2030). In 2030 alone, this saving could have been USD 7.8 Billion. It is pertinent to mention that these savings were only computed in lieu of the import reduction, and indigenization efforts, if made at various scales, would yield additional FOREX savings. The below graph represents the annual potential savings from the underlying measure (on account of import reduction):

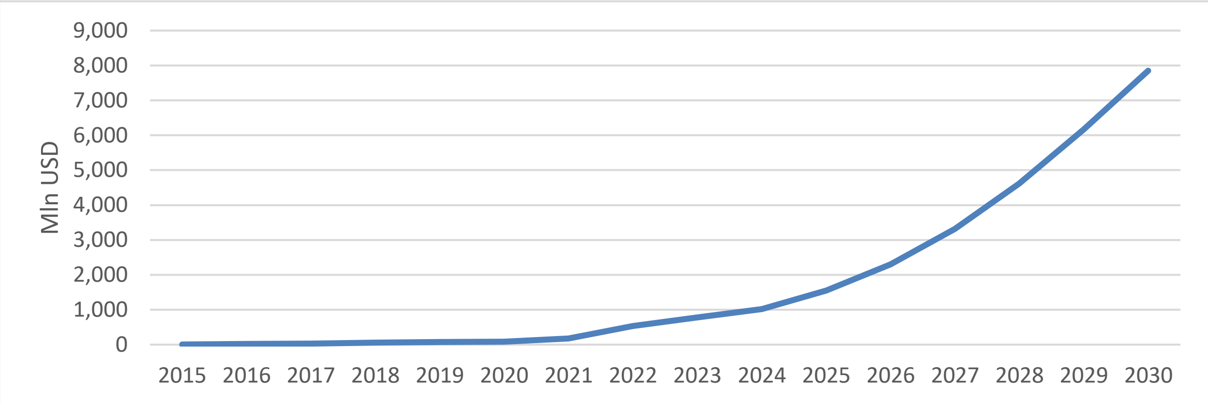


Figure 13. *Annual FOREX Savings from 2015 to 2030*

Conclusively, we may safely deduce from the results of what-if analysis that strategy for adoption of EVs should have been well-drafted and designed with the global boom to reach at the steep growth era by mid- late-2020s. This could have bestowed on us dividends spanning from flexible electricity demand growth, clean energy mix of the economy, significantly cleaner carbon footprint of the economy to considerably reduced magnitude of energy burden and FOREX drain. Moreover, this also proves that strategic planning and adoption of new technologies have benefits beyond the periphery of 5 to 10 years. Long term vision and plans have to be coined down with firm decision-making to enable a sustainable, clean, just and well-timed energy transition.

5.3. Economic Impact Assessment of EV Growth Scenarios

Next, we move to evaluating the EV deployment pathway and strategy moving forward. We shall be discussing all the economic impacts with 2024 as the starting point for EV deployment. As discussed earlier, the analysis has been segmented into three scenarios to illustrate the gravity of various pathways and their dividends.

In this case, we have evaluated EV growth strategy from 2024 up to 2030. We have applied the same Bass model. EV market share against each scenario is depicted below.

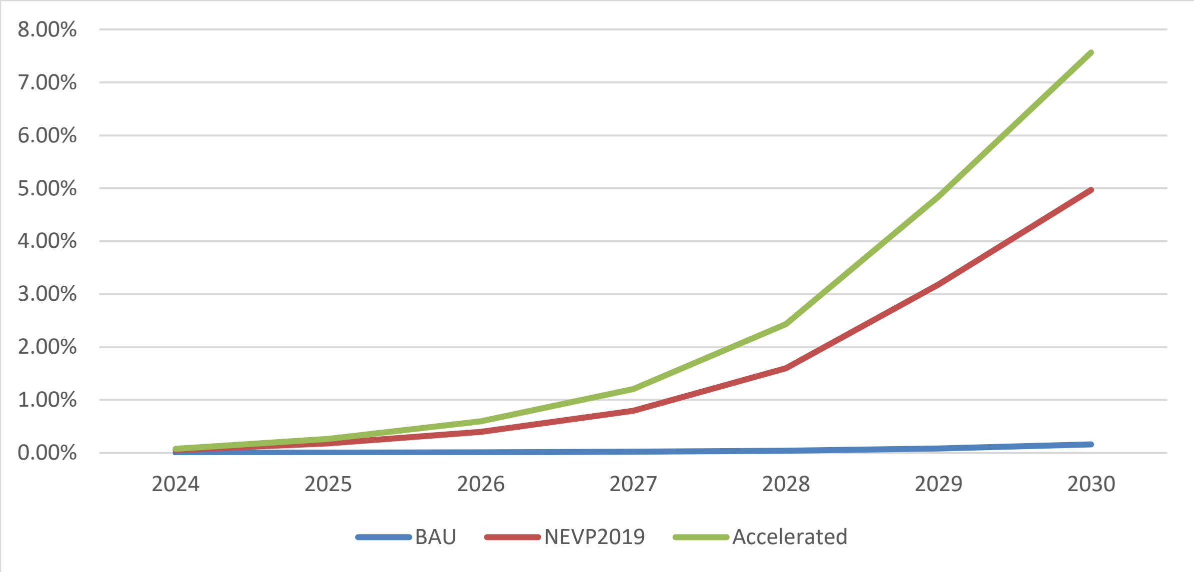


Figure 14. *Market Share of EVs in Total Vehicles (2024-2030)*

Further, we will be discussing the economic impacts of the EV roll-out in purview of the underlying scenarios.

5.3.1. Electricity Production Outlook and Demand

One of the most critical action items to foster the clean energy transition is electrification of energy demand (Birol, 2020). EV demand growth inherently unleashes the underlying objective along with shredding off demand from conventional petroleum. Added benefits also include efficiency gains that are packaged with the EVs.

In our scenario analysis, following electricity demand trend is observed.

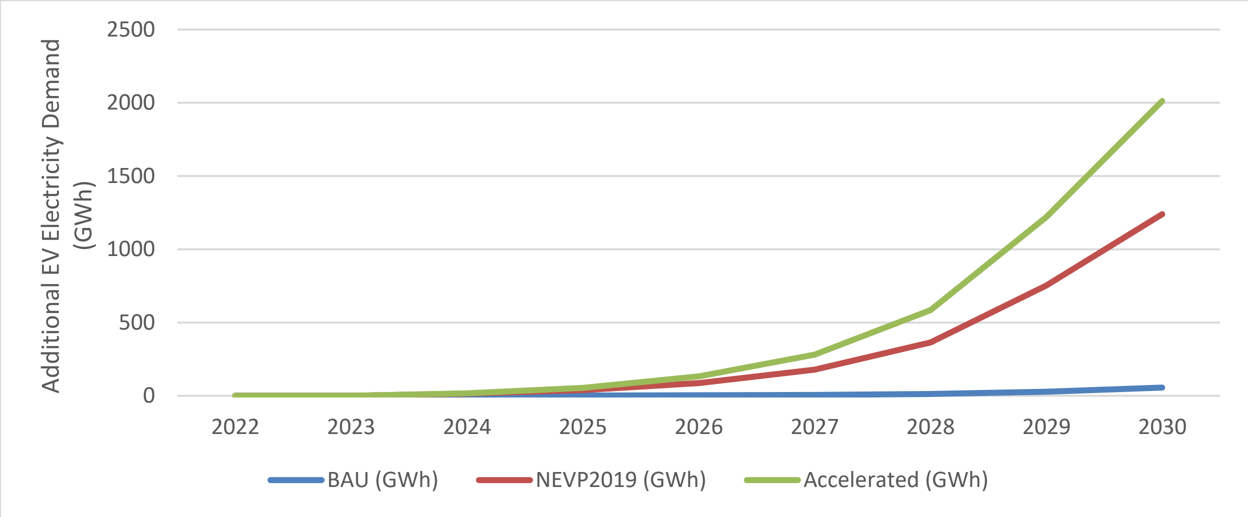


Figure 15. *Incremental Electricity Demand on Account of EV Demand Growth*

The above trends show that as-is trend would only land us into an EV demand of 56 GWh by 2030, whereas the NEVP2019 and accelerated EV pathways shall mark this pointer around 1239 and 2012 GWh, respectively. The share of EV demand in total electricity consumption shall be 0.03 percent, 0.57 percent and 0.92 percent for BAU, NEVP 2019 and Accelerated pathway scenarios, respectively.

It is obvious that the market adoption for EVs cannot achieve its maturity phase by up to 2030. However, this phase would require massive work around to attract investments, convince the potential vehicle buyers and replacers to opt for EVs and introduce incentives and subsidies that support EV adoption.

It is pertinent to mention that had this EV adoption strategy been implemented at accelerated scale commencing from 2015, the share of EV demand in total electricity demand could have been 12 percent.

Moving forward, the incremental energy mix would also be favoring energy transition. The changing incremental energy mix to cater for the additional EV growth is illustrated below.

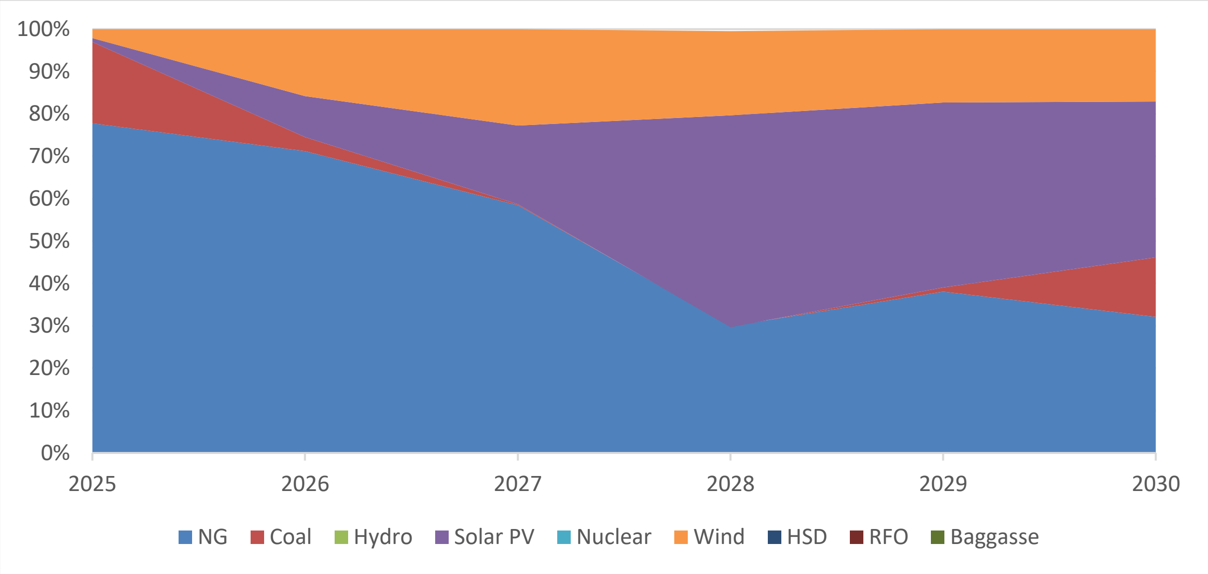


Figure 16. *Incremental Energy Mix of Electricity Generation to Cater for EV Demand*

The above trend shows that although in the initial years the share of clean energy technologies shall be small, the share of renewables grows as we move closer to 2030 and beyond. Henceforth, facilitating EVs shall be ultimately a contributing factor in facilitating adoption of renewables, i.e., in 2030 the NEVP2019 growth scenario shall require around 262MW of renewable capacity additions (208MW of solar and 54MW of wind) out of total required capacity of 350MW and Accelerated growth scenario shall require 337MW and 87MW of solar and wind capacity additions, respectively.

This indicates that such production side clean energy transition is well poised on least cost basis if EV demand grows and relies on the grid.

5.3.2. Energy Balance

As discussed above, if we consider EV growth strategy roll-out starting from 2024, the year of 2030 would lie within the innovator's phase, wherein the market maturity would have been still awaited. Henceforth, although the shift in energy balance shall be small in magnitude but if achieved, it would signalize the efficiency of the growth strategy that has to unleash great wins ahead. A glimpse from the shift in energy balance, in the transport sector of the economy, is shown below for the year of 2030.

Table 10. *Share of Primary Energy in Final Energy Consumption of Transport Sector*

Energy Consumption (KTOE)	Gasoline	Diesel	CNG	LPG	Electric	Efficiency	Total
BaseCase - No EV	8,075	16,616	444	10	0	**0**	**25,145**
Scenario 1 - BAU	8,063	16,598	444	10	5	**26**	**25,119**
Scenario 2 - NEVP2019 Growth	7,716	16,250	429	9	107	**634**	**24,511**
Scenario 3 - Accelerated Growth	7,523	16,010	420	9	173	**1,010**	**24,135**

All Figures are provided in kilotons of oil equivalent (KTOE) terms

5.3.3. Emissions

Although increasing the share of electrification to meet the energy demand does indeed enable achievement of net zero pathways and clean energy transition, it also depends on the production side energy mix and future energy trilemma priorities. This would call for a clear-cut vision and objective setting among the policymakers and energy regulators. These decision-makers need to agree on the weightage they put on the energy dimension legs of energy security, energy equity and sustainability. Here strategic energy security would further delve into accommodating indigenous energy resources, even if they are not clean. As per the latest IGCEP 2024, the local coal potential has been planned to be tapped for power generation. Of course, this may be debated among relevant stakeholders but from emissions perspective this move would not be very favorable. However, thanks to the grid parities of the renewable energies in the recent years, the least cost expansion plan of the national grid operator also opts for the solar and wind technologies to be added in the grid on annual basis. This aligns with the government vision as outlined in the National Electricity Policy 2021 to increase the share of indigenous and clean energy resources on annual basis. The analysis revealed that by 2030, the underlying scenarios shall post following emission footprints from the transport sector.

Table 11. Emissions of Pollutants on account of various EV Growth Scenarios

Pollutant	Unit	BaseCase - NO EV	Scenario 1 - BAU	Scenario 2 - NEVP2019	Scenario 3 - Accelerated Growth
CO_2	**Mtons**	79	79	77	76
SOx	**Tons**	7,066	7,070	7,141	7,191
NOx	**Tons**	54,176	54,126	53,023	52,319
PM2.5	**Tons**	22,093	22,070	21,619	21,310
VOCs	**Tons**	36,978	36,935	35,959	35,349

As per the assumed social cost parameters deduced from the NEVP 2019[16], this would imply that the NEVP2019 and Accelerated growth scenarios shall pay out a saving of modest USD 100 and 150 million on annual basis. Provided further, as learned from the What-if analysis, these savings would increase significantly in the next few years (beyond 2030).

5.3.4. Energy Burden

As discussed earlier in what-if analysis and *Table 9* above, the overall energy burden had inflated from 10.5 percent to 11.6 percent from 2016 to 2019. We know that the energy prices had again sat on the hot bed since 2022, coupled with the massive Pakistani rupee depreciation and double-digit inflation. This has apparently led to excessively high energy burden. The has been further vetted by the talk of the news and reports around. Henceforth, energy burden has to be made part of the problem narrative in the overall optimization matrix of the policymakers. How? Decisions should evaluate the possibility of allowing consumers enter into some energy independence. At the utility scale, adoption of local and cheaper energy resources may support the matter in long run.

If EVs are promoted with utilization of electricity from the grid for charging, the energy burden may be reduced to approximately 4.4 percent. And further to it, if the EV consumers are facilitated to adopt distributed energy system (behind the meter), this may reduce the energy burden by up to 5.2 percent in the long run.

[16] National EV Policy 2019 conservatively assumes socio-economic costs of carbon emissions for Pakistan to be around USD 50 per metric ton.

5.3.5. Foreign Exchange

From our analysis, we understand that due to the innovator's phase of the technology diffusion curve, the FOREX savings are not very significant. However, the stipulated impacts shall bear the tidings of rate of success of the strategy. The results from the FOREX impact analysis are appended below.

Table 12. Total FOREX (Million USD) Requirement in each EV Growth Scenario

Mln USD	**BaseCase No EV**	**Scenario 1 - BAU**	**Scenario 2 - NEVP2019 Growth**	**Scenario 3 - Accelerated Growth**
2024	13,297	13,297	13,292	13,292
2025	13,813	13,812	13,799	13,794
2026	14,344	14,343	14,313	14,297
2027	14,851	14,849	14,787	14,751
2028	15,365	15,361	15,232	15,155
2029	15,903	15,894	15,625	15,461
2030	16,438	16,419	15,979	15,706

The NEVP2019 growth scenario yields a cumulative FOREX savings of approx. USD 1 Billion in 7 years (2024-2030), whereas Accelerated growth scenario is supposed to save around USD 1.5 Billion in the same period. For an economy like Pakistan, such savings would in any case mean moderate wins.

CHAPTER 6:

CONCLUSION AND POLICY RECOMMENDATIONS

6.1. Conclusion

The study conducts a thorough assessment of Pakistan's National Electric Vehicle Policy (NEVP 2019) utilizing a multifaceted approach that includes both qualitative and quantitative analysis. The main tasks involve conducting a thorough evaluation of NEVP 2019 using the OECD policy evaluation framework, predicting the growth of EVs under different scenarios using the Technology Diffusion Theory and Bass Model, performing a what-if analysis to explore the potential economic effects if the EV rollout had started earlier, and evaluating the economic consequences of different EV rollout scenarios commencing from 2024.

The NEVP 2019, while having good intentions, is deficient in key components such as a concise vision statement, comprehensive monitoring and implementation mechanisms, and a full breakdown of the budget. Although the strategy addresses some of Pakistan's economic limitations, it does not effectively promote the rapid adoption of EVs during the initial phase of innovation. Implementing EVs can make a substantial impact in diminishing GHG emissions, lowering dependence on fossil fuels, and enhancing long-term energy security. The economic research suggests that customers might potentially save money by reducing their energy expenses, and it could also have a positive impact on the national economy by decreasing the need for fuel imports. The NEVP2019 growth scenario predicts a total foreign exchange saving of about USD 1 billion from 2024 to 2030. However, an accelerated growth scenario has the potential to save approximately USD 1.5 billion within the same time frame.

The high cost of vehicles and inadequate charging infrastructure provide major obstacles to the widespread adoption of EVs. These challenges are exacerbated by the absence of government support, which further deteriorates the confidence of the consumers and prospective manufacturers / investors from the policy directives. The existing incentive regime is insufficient and vague in promoting the required transition towards clean electric mobility. A more robust system of incentives with clarity and credibility needs to be established with consumer centric and producer friendly platforms that allow vehicle buyers to opt for EVs at the time of buying decisions.

Based on our comprehensive analysis and evaluation of the findings, we present many policy recommendations aimed at enhancing the effectiveness and implementation of the NEVP 2019. The most critical area of improvement is the establishment of a monitoring and implementation mechanism. Establishing a dedicated institutional structure or delegating the mandate to an existing relevant institution to oversee the implementation of the NEVP 2019, ensuring compliance with the policy, and identifying areas for improvement are the most needed areas of action. In order to achieve the policy stipulations and ensure their successful implementation, further actions have to be taken including, inter alia, formulation protocol for review, feedback, and policy adjustment mechanism. Additionally, creating clear lines of responsibility and governance structures would contribute to its efficacy and resilience. Creating an inter-ministerial group of members from many sectors will ensure a synchronized and effective implementation of policy across different sectors. Facilitating stakeholder engagement and information sharing through conversations and workshops promotes confidence and trust among producers and customers.

Comprehensive financial planning and allocation of cash are crucial to uphold the goals of the policy. By exploring innovative financing tools and strategies such as, inter alia, green bonds and public-private partnerships, renewable credits, clean energy certificates and integration with the other retail sectors, it is possible to broaden the consumer acceptability to opt for EVs during their vehicle buying decisions. A recommended strategy would include identifying specific value chains in the manufacturing line and allowing phased approach in indigenization, taking inspiration from successful examples such as India's Production Linked Incentive (PLI) Scheme. Establishing an extensive network of charging infrastructure and service centers is crucial to instill confidence among the potential EV consumers as aftersales services contribute substantially to buying decisions. Allowing EVs to be charged from decentralized installations, such as rooftop solar panels, can promote a more ecologically conscious transition to greener energy sources. Developing a well-designed power price scheme for EV users is of utmost importance, considering the classification of various income levels and their specific needs.

It is essential to offer government assurances in order to instill confidence among stakeholders and create a conducive climate for the adoption of EVs. Providing financial assistance and investment in research and development (R&D) would encourage the growth of local manufacturing and ensuring that EV technologies are customized to meet the specific requirements of Pakistan. Pakistan may achieve its clean energy goals by following these suggestions, which would enable a sustainable and just shift towards EVs, and hence clean and sustainable energy transition. To successfully implement these recommendations, it is essential for various stakeholders to work together in a coordinated manner. This collaboration will ensure a smooth, efficient, and beneficial shift towards electric mobility.

6.2. Policy Recommendations

The study clearly identifies that focus has to paid to following aspects and decision items:

1. Indigenization venues and potential pathways have to be identified and have end-to-end steps laid down. India’s massive multi-sectoral Production Linked Incentive (PLI) Scheme is a popular and successful benchmark in this regard.

2. To enable accelerated, just and cleaner energy transition, the policymakers need to converge on the scale and scope of the distributed generation (mainly rooftop solar).

3. Predictable and credible policy and regulatory regime – a setting that facilitates smooth transition of consumers and investor confidence.

4. Designing of a well-thought electricity tariff package for the EV consumers – this may also require segmenting various income groups. Segregation in this regard may be possible through bottom-up approaches (e.g., individual account / card system, direct debit, etc.) or top-down (different charging tariffs at charging kiosks for 2/3 wheelers and 4 wheelers) and separate tariff category for public transit systems (keeping in view that beneficiaries for public transit system would be the lowest income groups).

5. Development of institutional players that may steer the process independent of the political priorities and shifts – this may support persevering through the initial innovator phase.

6. Devise strategies to attract foreign direct investments in the underlying area. CPEC may open up some potential opportunities in this regard, provided that some of the largest and most popular EV manufacturers are now becoming prominent in China.

7. Foster stakeholder engagement and awareness through various dialogues, sessions, etc.

8. Monitoring, implementation and accountability framework of the National Electric Vehicle Policy 2019 has to be strengthened to enable smooth operationalization of the stipulated policy objectives, targets and clean energy transition in the mobility sector.

9. EV Policy requires institutional *guardianship*. This may be fulfilled by the envisaged Inter-Ministerial Committee on Electric Vehicles. Moreover, development of an implementation plan is the need of the hour to enable precisely trackable, measurable and tangible roadmap for the promulgation and adoption of EVs at all scales.

10. Discovery and determination of the budgetary layout of the EV rollout scheme has to be carried out to enable fiscal clarity and financial planning. The same needs to be outlined in the policy framework.

11. The benchmarking process has to be strengthened to enable application of global best

practices in enabling deployment of EVs on sustainable ground and accelerated pace.

12. The energy equity and energy justice element have to be well-planned, and an in-depth thought process has to be performed to ensure that the lowest income groups also reap the advantages of the mobility transition at an optimal stage of the EV promulgation.

If we take some serious steps now, we shall be set to achieve some big wins by 2040 in terms of energy independence, net zero targets, nationally determined contributions and much more!

REFERENCES

Aasheesh Dixit. (2020). A Review of India’s EV Policy. *IAEE Energy Forum*.

Babar, A. H. K., Ali, Y., Khan, A. U. (November 2020) *Moving toward green mobility: overview and analysis of electric vehicle selection, Pakistan a case in point*

Barkoczi, Nadia; Lobonţiu, Mircea; Bacali, Laura. (2015). *Predicting The Adoption by the Young Consumers of a New Technology on the Mobile Phone Market using the Bass Diffusion Model*

Barrett, S. R. H., Supervisor, A. T., & Yang, M. (2013). *Climate and Air Quality Impacts of Electric Vehicles and Comparison to U.S. Tax Credits*.

Becker, T. A., Sidhu, I., & Tenderich, B. (2009). *Electric Vehicles in the United States A New Model with Forecasts to 2030*.

Benjamin T. (2023). *Life-cycle GHG emissions of an EV compared to an ICEV*

Cai, W., Wang, C., Chen, J., & Wang, K. (2014). Green economy and green jobs: Myth or reality? The case of China's power generation sector. Energy, 75, 127-136.

Chen, Y., Ji, Q., Zhang, D., & Pan, J. (2021). Electric vehicles in China: Emissions and health impacts. Environmental Science & Technology, 55(1), 16-29.

Chen, Z., Carrel, A. L., Gore, C., & Shi, W. (2021). Environmental and economic impact of electric vehicle adoption in the U.S. *Environmental Research Letters*, *16*(4). https://doi.org/10.1088/1748-9326/abe2d0

Colin Sheppard, Julia Szinai, Nikit Abhyankar, Anand R. Gopal (2019). “*Grid Impacts of Electric Vehicles and Managed Charging in California; Linking Agent-Based Electric Vehicle Charging with Power System Dispatch Models*”, Energy Analysis and Environmental Impacts Division Lawrence Berkeley National Laboratory, Sustainable Transportation Initiative

Cornell, R. (2017). *The Environmental Benefits of Electric Vehicles as a Function of Renewable Energy*.

Creutzig, F., et al. (2015). "Transport: A roadblock to climate change mitigation?" *Science*, 350(6263), 911-912.

Gallagher, K. S., & Muehlegger, E. (2011). "Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology." *Journal of Environmental Economics and Management*, 61(1), 1-15.

Glerum, A., Stankovikj, L., Thémans, M., & Bierlaire, M. (2014). Forecasting the demand for electric vehicles: Accounting for attitudes and perceptions. *Transportation Science*, *48*(4), 483–499. https://doi.org/10.1287/trsc.2013.0487

Hardman et al. March 2018. Driving the Market for Plug-in Vehicles: Understanding Financial Purchase Incentives. https://phev.ucdavis.edu/wp-content/uploads/understanding-financial-purchaseincentives.pdf.

Harvey, L. D. D. (2020). Rethinking electric vehicle subsidies, rediscovering energy efficiency. *Energy Policy*, *146*. https://doi.org/10.1016/j.enpol.2020.111760

HDIP. (2021). *Energy Year Book 2021, Hydrocarbon Development Institute of Pakistan, Ministry of Energy (Petroleum Division)*.

He, X., Guo, Y., & Peng, X. (2019). Technological innovation in lithium-ion batteries: A review. Journal of Power Sources, 414, 259-269.

He, X., Zhang, S., Wu, Y., Wallington, T. J., Lu, X., Tamor, M. A., McElroy, M. B., Zhang, K. M., Nielsen, C. P., & Hao, J. (2019). Economic and Climate Benefits of Electric Vehicles in China, the United States, and Germany. *Environmental Science and Technology*, *53*(18), 11013–11022. https://doi.org/10.1021/acs.est.9b00531

Hodge, C., O’Neill, B., and Coney, K, (2020). Effectiveness Of Electric Vehicle Policies and Implications For Pakistan. National Renewable Energy Laboratory

Holland, S. P., Mansur, E. T., Muller, N. Z., & Yates, A. J. (2015). *ENVIRONMENTAL BENEFITS FROM DRIVING ELECTRIC VEHICLES?* http://energy.gov/articles/history-electric-car.

IEA (International Energy Agency) (2020). "Global EV Outlook 2020." Paris: IEA Publications.

IEA (International Energy Agency) (2023). "Global EV Outlook 2023." Paris: IEA Publications.

Jaffe, A. B., & Stavins, R. N. (1994). *What does it mean ?*

Jonathan E., Samuel Kortum (2001). International Technology Diffusion: Theory and Measurement

Kumar, R. R., & Alok, K. (2020). Adoption of electric vehicle: A literature review and prospects for sustainability. In *Journal of Cleaner Production* (Vol. 253). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.119911

Kumar, R. R., Guha, P., & Chakraborty, A. (2022). Comparative assessment and selection of electric vehicle diffusion models: A global outlook. *Energy*, *238*. https://doi.org/10.1016/j.energy.2021.121932

Leif S. (2016). *On the Diffusion of Innovations: How New Ideas Spread*

Lieven, T. (2015a). Policy measures to promote electric mobility - A global perspective. *Transportation Research Part A: Policy and Practice*, *82*, 78–93. https://doi.org/10.1016/j.tra.2015.09.008

Lieven, T. (2015b). Policy measures to promote electric mobility - A global perspective. *Transportation Research Part A: Policy and Practice*, *82*, 78–93. https://doi.org/10.1016/j.tra.2015.09.008

Lutsey, N., & Nicholas, M. (2019). "Update on electric vehicle costs in the United States through 2030." *International Council on Clean Transportation*.

Martins, H., C.O. Henriques, J.R. Figueira, C.S. Silva, A.S. Costa (2023). *Assessing policy interventions to stimulate the transition of electric vehicle technology in the European Union* https://doi.org/10.1016/j.seps.2022.101505

Martin W., Martin K. P., Martin J., Adolfo P., Pierre B., Geert V. G. (2012). On the electrification of road transport - Learning rates and price forecasts for hybrid-electric and battery-electric vehicles

Naveen A. (2024). EV adoption: moving customers along the funnel

NEPRA (2022). NATIONAL ELECTRIC POWER REGULATORY AUTHORITY (ELECTRIC POWER PROCUREMENT) REGULATIONS, 2022

NATIONAL ELECTRIC VEHICLE POLICY (2019), Ministry of Climate Change, Government of Pakistan.

MoCC. (2021). *Updated Nationally Determined Contributions 2021, Ministry of Climate Change, Government of Pakistan*.

Nam, Ho-Hun Yang, Kwang-Min. (2008). *An Empirical Study of Technology Diffusion on the Internet using Bass Model*

National Transport Research Centre. (2022). *NTRC Study on Freight Transport (Trucking) in Pakistan*.

Naveed Arshad, Nauman Ahmad Zaffar, Mohammad Abubakr, Javed Malik, & Muhammad Arslan. (2021). *PAKISTAN: ELECTRIC VEHICLES AND BATTERIES MARKET ASSESSMENT*. https://lei.lums.edu.pk/

Netschert, B. (2018). Economic impacts of electrification in the transportation sector. Energy Policy, 113, 342-351.

Netschert, B. C. (2018). *The Economic Impact of Electric Vehicles*.

Noel, L., Zarazua de Rubens, G., Kester, J., & Sovacool, B. K. (2018). Beyond emissions and economics: Rethinking the co-benefits of electric vehicles (EVs) and vehicle-to-grid (V2G). *Transport Policy*, *71*, 130–137. https://doi.org/10.1016/j.tranpol.2018.08.004

Noel, L., Zarazua de Rubens, G., Kester, J., & Sovacool, B. K. (2018). Understanding the socio-technical nexus of Nordic electric vehicle (EV) barriers: A qualitative discussion of range, price, charging, and knowledge. Energy Policy, 123, 165-173.

OECD. (2021). *Applying Evaluation Criteria Thoughtfully*. OECD. https://doi.org/10.1787/543e84ed-en

Pg-Abas, A. E., Yong, J., Mahlia, T. M. I., & Hannan, M. A. (2019). Techno-economic analysis and environmental impact of electric vehicle. *IEEE Access*, *7*, 98565–98578. https://doi.org/10.1109/ACCESS.2019.2929530

Pirmana, V., Alisjahbana, A. S., Yusuf, A. A., Hoekstra, R., & Tukker, A. (2023). Economic and environmental impact of electric vehicles production in Indonesia. *Clean Technologies and Environmental Policy*, *25*(6), 1871–1885. https://doi.org/10.1007/s10098-023-02475-6

Prud'homme, R., & Koning, M. (2012). Electric vehicles: A tentative economic and environmental evaluation. *Transport Policy*, *23*, 60–69. https://doi.org/10.1016/j.tranpol.2012.06.001

Rumi Aijaz. (2022). *Electric Vehicles in India: Filling the Gaps in Awareness and Policy, Observer Research Foundation*.

Salisbury, M. (2013). *Air Quality and Economic Benefits of Electric Vehicles in Arizona*. http://www.eia.gov/state/?sid=AZ

Salisbury, D. (2013). Economic and environmental impacts of electric vehicle adoption. Environmental Science & Technology, 47(11), 5481-5490.

Segal, R. (1995). Forecasting the Market for Electric Vehicles in California Using Conjoint Analysis. In *Source: The Energy Journal* (Vol. 16, Issue 3).

Selvakkumaran, S., Ahlgren, E. O., Winyuchakrit, P., & Limmeechokchai, B. (2018). *ICUE 2018 on Green Energy for Sustainable Development Thavorn Palm Electric Vehicle (EV) Transition in*

Thailand: Is it Beneficial?
Shakeel, U. (2022). *Moving toward green mobility: overview and analysis of electric vehicle selection, Pakistan a case in point*
Sheldon, T. L., Rubal, D. (2024). *The dynamic role of subsidies in promoting global electric vehicle sales*. https://doi.org/10.1016/j.tra.2024.104173
Sheldon, T. L. (2022). *Evaluating Electric Vehicle Policy Effectiveness and Equity*. https://doi.org/10.1146/annurev-resource-111820
Sierzchula, W., Bakker, S., Maat, K., & Van Wee, B. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy*, *68*, 183–194. https://doi.org/10.1016/j.enpol.2014.01.043
Sillup, George P (1992). *Forecasting the adoption of new medical technology using the bass model*
Sovacool, B. K. (2017). Contestation, contingency, and justice in the Nordic low-carbon energy transition. Energy Policy, 102, 569-582.
Van Der Steen, M., Van Schelven, R. M., Kotter, R., Van Twist, M., & Van Deventer Mpa, P. (2015). EV policy compared: An international comparison of governments' policy strategy towards E-mobility. *Green Energy and Technology*, *203*, 27–53. https://doi.org/10.1007/978-3-319-13194-8_2
Wang, N., Tang, L., & Pan, H. (2019). A global comparison and assessment of incentive policy on electric vehicle promotion. *Sustainable Cities and Society*, *44*, 597–603. https://doi.org/10.1016/j.scs.2018.10.024
Wu, M., & Chen, W. (2022). Forecast of Electric Vehicle Sales in the World and China Based on PCA-GRNN. *Sustainability (Switzerland)*, *14*(4). https://doi.org/10.3390/su14042206
Zhang, T., Paul J. Burke, Qi Wang. (2024). *Effectiveness of electric vehicle subsidies in China: A three-dimensional panel study* https://doi.org/10.1016/j.reseneeco.2023.101424
Zhebin S, Chenxu Z., Zhihai Y. (2018). *An Optimizing Power System Dispatch with An Extra EV Load Using PLEXOS Approach*