Electric Vehicles in Pakistan:
Policy Recommendations

USPCAS-E

USAID
FROM THE AMERICAN PEOPLE

LUMS | Energy Institute

Electric Vehicles in Pakistan:
Policy Recommendations
Volume I
Cars

January 2019
Rabi' al-Thani 1440

This report has been prepared by LUMS energy institute in collaboration with U.S.-Pakistan Centre for Advanced Studies in Energy (USPCAS-E) at UET-Peshawar.

About the LUMS Energy Institute

This Energy Institute at LUMS is established to serve as a think tank, centre of technical excellence, knowledge network, and capacity building ground for the Pakistan to institutionalize a renewable rich future for Pakistan in the most sustainable and cost-effective way possible.

About USPCAS-E

The USPCAS-E's mission is to support Pakistan's economic development by strengthening the relevance and responsiveness of university products, including applied and policy research and skilled graduates, to the needs of the public and private sector. The centre encourages and empowers women engineers and researchers to actively participate through equal opportunities.

Project Principal Investigator:

Dr. Naveed Arshad, Associate Professor, LUMS

Co-Principal Investigator:

Dr. Najeeb Ullah, Deputy Director USPCAS-E, UET-Peshawar

Co-Authors:

Basit Tanvir Khan, Mohammad Abubakr Javed, Malik Muhammad Arslan, Muhammad Hammad Qureshi

Preface

The year 2017 was perhaps a defining moment in road transportation when many countries around the globe announced their policies for Electric Vehicles (EVs). Some countries went as far as announcing plans to completely halt sale of Fossil Fuel Vehicles (FFVs). Norway plans to ban sale of all FFVs by 2025, Netherlands plans to ban such sales by 2030, while France and UK plan to do the same by 2040. Other countries such as China, Germany, Sweden and many US States have announced ambitious plans for EV penetration in their respective locales. While EVs have been around for many years, many experts see the policies announced in 2017 as a trigger for mass adoption of EVs. Even developing countries like India have announced to increase their share of EVs sale to 30 percent and completely shift to all electric buses by 2030.

After the policy announcements, the automotive manufacturers also followed suit and announced plans to massively increase their EV line up in the coming years. Some like Volvo went far as by announcing plans to eliminate FFVs from their list. Some manufacturers, who do not have many EVs in their line-up such as Toyota and Suzuki, have bowed to the trend and announced partnerships and plans to bring EVs to their production list by 2020. In fact, Suzuki is launching their first EV in India in 2020, even before its Japan's launch.

Therefore, there is no doubt that governments and manufacturers have realized that EVs are the future mode of road transportation. Of course, the very basic ingredient of EV is availability of electricity. Therefore, whenever we discuss EV adoption in the context of Pakistan, the first question we always face is about the shortfall of electricity in Pakistan and whether we have enough electricity to even bring a handful of such vehicles in Pakistan. Before delving into the detailed report, it is prudent to mention that Pakistan has enough spare electricity capacity to easily launch EVs. Of course this statement may come as a surprise to many but let us qualify this statement.

Pakistan used 107 TWh of electricity in 2017 with around 33,000 MW of installed capacity, which is a well-known number available in power sector reports. However, what is not reported often is that we had 42 TWh of spare electricity generation capacity that we were not able to utilize but still paid capacity payments amounting to 350 billion in year 2017. Some of this unutilized electricity is due to Transmission and Distribution (T&D) losses but most of it is due to intraday and seasonal variations of electricity demand. The demand in Pakistan varied between 8,000 MW to around 26,500 MW in 2017. This spare 42 TWh is more than enough to shift much of the transportation fleet of the country on electricity. Of course electricity is not the only requirement in introducing EVs on mass scale.

Moreover, Pakistan is going to touch a peak generation capacity expansion of 62,000 MW by 2025 while our peak demand may just touch 40,000 MW. Sparing the outages and seasonal variation, we will still have excess capacity at all times of the year. In fact, if we do not use the spare capacity and do not find new loads for the grid, the capacity payments of unutilized

electricity will amount to approximately 1500 billion by 2025.

Other than capital expenditure, the cost of running EVs is considerably attractive. We have calculated that, while FFVs runs one kilometre for ten rupees with the present fuel cost, an equivalent EV can cover the same distance using only three rupees at the current domestic electricity rates. The capital cost of purchasing EVs is high at this time but is expected to reach parity with FFVs in the next few years. Until that time, to encourage EV penetration, many countries in their EV policies have slashed the taxes and duties to zero and have provided further tax rebates to encourage large scale adoption of EVs.

This report is a humble effort in looking at the current landscape and suggesting ways to introduce EV value chain in the country. The Government of Pakistan has reduced duties and taxes on EVs and charging stations in the FY 18-19 budget. However, such incentives are only part of the equation. EVs are a whole new industry and requires a paradigm shift in how we think about electrification of road transportation.

This policy recommendation report is not a static report where the reader is only getting one-way information. In order to make this report interactive, we have developed three simulators encompassing various aspects of EVs. The first simulator simulates EV load on the grid, the second simulates cost comparison of EV vs. FFV, while the third simulates the fuel saved by EVs. These simulators are available at the companion website of this report at the following URL: Http://web.lums.edu.pk/~eig

We would like to thank our sponsors who made it possible for us to work on this initiative. The sponsors include USPCAS-E, which is a USAID funded project, and Bilquis and Abdul Razak Dawood (BARD) Foundation, which has provided the seed funding for the Energy Institute at LUMS. Also, we would like to acknowledge valuable contributions from Ignite National Technology Fund that supported the Principle Investigator (PI) through its multiple funded projects. It is noteworthy to mention Higher Education commission (HEC) for its support for the National Centre in Big Data and Cloud Computing (NCBC) at LUMS and in particular, the federally funded Sustainable Energy Informatics Lab (SEIL). Last but not the least, LUMS has provided funding for almost all blue sky initiatives that PI has undertaken in the past several years. This report is a product of some of those blue sky research initiatives. Unrestricted funding for blue sky initiatives has made LUMS stand out from the rest of the research oriented institutions in Pakistan and we are particularly thankful to LUMS management for their continued support.

We hope you enjoy reading this report. As academicians and researchers, we would appreciate your feedback and look forward to see this report as a stepping stone towards National EVs Policy of Pakistan.

Dr. Naveed Arshad, Dr. Najeeb Ullah

Contents

List of Figures

List of Acronyms

EV……Electric Vehicle
FFV……Fossil Fuel Vehicle
PM……Particulate Matter
NEEDS……National Economic and Environment Development Study
SO_2……Sulphur Dioxide
NO_2……Nitrogen Dioxide
NTDC……National Transmission and Despatch Company
BEV……Battery Electric Vehicle
HV……Hybrid Vehicle
PHEV……Plug-in Hybrid Electric Vehicle
FBR……Federal Board of Revenue
NEPRA……National Electric Power Regulatory Authority
CBU……Completely Built Unit
CKD……Completely Knocked Down
R&D……Research and Development
CPEC……China-Pakistan Economic Corridor
GHG……Green House Gases
IPP……Independent Power Producers
GBG……Green Banking Guidelines
USD……United States Dollar
PKR……Pakistan Rupee
T&D……Transmission and Despatch
TWh……Tera Watt Hours
MWh……Mega Watt Hours
PI……Principle Investigator
HEC……Higher Education commission
NCBC……National Centre in Big Data and Cloud Computing
SEIL……Sustainable Energy Informatics Lab
BARD……Bilquis and Abdul Razak Dawood

Executive Summary

Pakistan is facing several multi-sectoral and multi-faceted challenges. Therefore, solutions that impact several sectors in a positive way are direly needed. In this policy recommendation report, we argue that introducing EVs in Pakistan can solve present and impending problems of a number of sectors including transportation, environment, economy and power. The term EV covers a wide range of transportation options including motorcycles, buses, trucks and cars. This particular report is for cars only. For the other three, we will be presenting an addendum to this report at a later date.

The transportation sector has been growing with a double digit growth in Pakistan. Almost all of the transportation sector is dependent on oil-based products and the country is spending almost USD 13 billion on the import of oil every year [34]. If our transport sector continues to grow at the same double digit rate, the bill for oil import is expected to reach USD 30 billion by 2025.

Pakistan has already been declared as the seventh most vulnerable country due to the effects of climate change [36]. Burning more fossil fuels, including oil, may only deteriorate the situation further. According to the National Economic and Environment Development Study (NEEDS) report, Pakistan is expected to double its emissions by 2020 and further doubling it by 2030 [35]. Not only carbon emissions will increase but also other hazardous compounds such as Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2) and particulate matters (PM), PM10 and PM2.5, will also increase in the atmosphere due to an increase in burning of fossil fuels. Most major cities in Pakistan have already crossed the threshold of clean air by a wide margin [30]. Over three hundred thousand people die due to poor air quality in Pakistan every year [43].

The power sector in Pakistan has also faced challenges and for the past decade, the power generation has not been able to fulfil the power demand of the country. However, in the next several years, the situation is going to change rapidly and Pakistan will have a glut of power generation. According to estimates of National Transmission and Dispatch Company (NTDC), the country has already signed up for new generation that will take its total power generation capacity to 62,184 MW peak generation [24]. Sparing unscheduled outages of almost 55,000 MW will be available during the peak demand times of the year [24]. However, the uptake in demand at 7 percent GDP growth rate is expected to be close to 40,000 MW in 2025 [24]. This means that an excess of 15,000 MW peak generation capacity will be available in the system by 2025. Unfortunately, most of this power generation is under ‘take or pay’ contracts which means even if the government does not buy this power, a hefty capacity charge payment is unavoidable.

The triple blow of ballooning fuel bill payments, environmental degradation, and capacity charge payments will create major challenges for the country over the next several years. We strongly believe that introducing EVs in the country, with the right policy framework, will not only ameliorate the three aforementioned problems but also will help in job creation and economic growth.

In Pakistan, EVs can readily utilize the power

supply glut in the next several years. According to our estimates, after taking into account all the transmission and distribution losses, almost 500,000 EVs can be fully charged daily with a supply of just under 1000 MWs. Due to the efficiency of battery based energy storage, EVs can give the same mileage with one-third of the cost compared to their FFV rivals. Moreover, due to this efficiency, even if EVs are charged with fossil fuel based electricity generation sources, such as natural gas or coal, almost 25-40 percent fuel can be saved due to the higher electricity generation efficiency of larger units. This directly translates into a lower import bill. Additionally, EVs require minimal maintenance and does not need oil and other lubricant changes which further reduces imported oil requirements.

Almost 37 percent electricity generation in Pakistan is from renewable sources. Adding this to the efficiency of EVs results in 70-80 percent less environmental emissions when compared to FFVs. This means that, while the tail pipe emissions of EVs are zero, the overall impact of EVs is around 70-80 percent reduction in environmental emissions in the overall energy value chain.

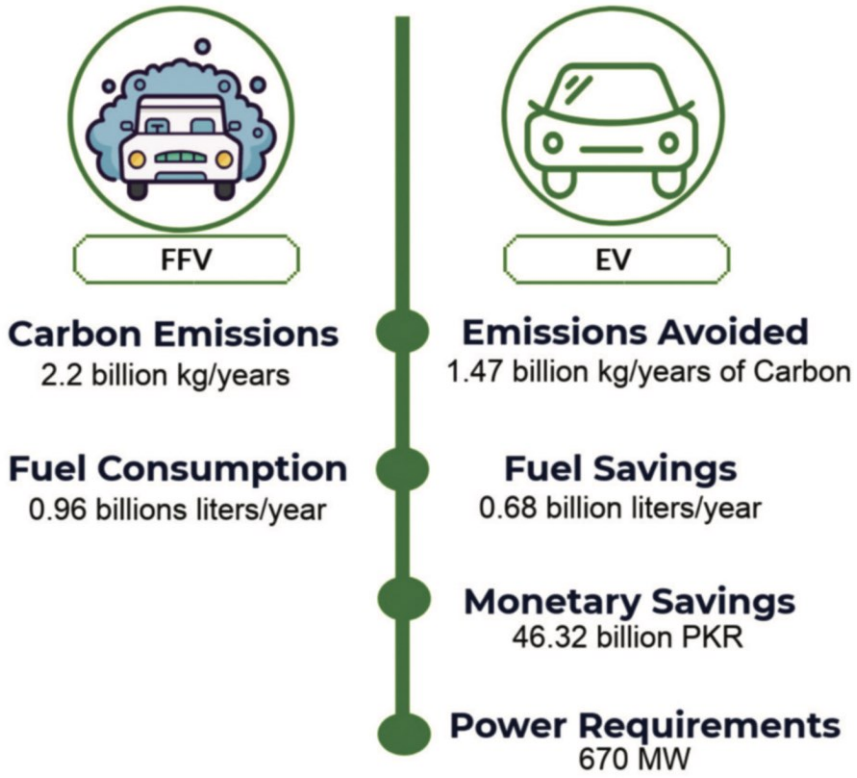
EVs are of several types, broadly categorized as Hybrid Vehicles (HVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles or also called EVs. HVs are self-contained vehicles that have a small battery, typically in the range of 1-3 kWh. The engine and the braking charges the battery and the car's computer system switches between the engine and battery power or between a combination based on speed and driving patterns. PHEVs, in addition to an engine and a large battery, which typically has a capacity of 10-15 kWh, have an option to charge the battery from an electric outlet. Typical range of PHEVs, with fully charged batteries, is 30-50 km. Once the battery depletes, the engine kicks in and the PHEVs then work as HVs. EVs are fully electric cars in which the battery capacity ranges from 30 kWh to 60 kWh. Battery Electric Vehicles (BEVs) have to be charged from electric outlets and the typical driving range with one full charge is between 150- 300 km. If EVs are the ultimate goal of electrification of road transportation, PHEVs provide an interesting path towards achieving this goal.

The goal of all EVs is not an ordinary goal. Thus, it may not be achieved until a couple of decades for even the most advanced countries in the world. Therefore, countries have set deadlines to go all electric in their new car sales. Norway is planning to sale all EVs by 2025 [11]. Netherlands is planning for 2030, while UK and France are targeting a deadline of 2040 for all EV sales [11]. Even India has a target to sale 30 percent of new vehicles as all electric cars by 2030 [11]. Due to these targets, several automakers are also set to remove fossil fuel based vehicles (FFV) from their vehicles line up. Volvo is all set to remove complete FFVs from its line up and plans to increase BEV share to 50 percent by 2025 [38]. Similarly, all major automakers have targets to increase their share of PHEVs and BEVs through new models and targets in the next several years.

In short, a revolution is taking place in the transportation sector and a move towards electrification of the transport sector is inevitable. However, we would like to stress that our move towards EVs should not be a 'knee jerk' reaction, rather it should be a calculated policy move that takes into account our strengths, opportunities and limitations. Never would we like to be in a situation where EVs create a Compressed Natural Gas (CNG) like fiasco. Careful policy evaluation is also important as EVs directly impact the power sector entities, and several key stakeholders in the value chain such as Federal Board of Revenue (FBR), Federal/Provincial Ministry of

Finance, Federal/Provincial Ministry of Energy, Federal/Provincial Ministry of Climate Change, power distribution companies, National Electric Power Regulatory Authority (NEPRA), NTDC and the Ministry of Commerce. Many new automakers are starting production in Pakistan including Kia, Hyundai, Renault
and others. This can give us a promising opportunity to introduce EVs in Pakistan at a rapid rate.

For EVs to be successful, a large and well spread- out charging infrastructure is essential. However, the number of EVs and charging infrastructure is a 'chicken and egg' problem. Charging infrastructure only makes commercial sense if enough EVs are on roads while EVs require charging infrastructure to get rid of the so called 'range anxiety' phenomena and that requires sufficient penetration of charging infrastructure. However, with careful planning and policy intervention, this problem can be worked out.



Comparison of EVs vs. FFVs (assuming 0.5 million EVs on road)

Policy Recommendations

While the running cost of EVs is one third of FFVs, the capital cost is quite high. Therefore, we propose that the duty and taxes for EVs should be reduced to 5%. Initially, the government can give this relaxation to Completely Built Units (CBUs) but by 2020-21 this exemption should only be offered to Completely Knocked Down (CKDs) units, so as to encourage the local automakers to manufacture EVs in Pakistan. As explained later in the report, the savings from energy efficiency of EVs can repay these taxes in other forms such as fuel savings and reduction in oil import bill, not to mention the environmental savings that results from lesser emissions. Additionally, provinces should also be encouraged to reduce registration fees and token taxes on EVs.

To encourage EVs without the range anxiety problem and in the absence of charging infrastructure, the same duty and tax relaxation should be on PHEVs as well. PHEVs provides the best of both worlds and could serve as an intermediary to BEVs until sufficient charging infrastructure is in place.

The charging infrastructure may need to be in place at major cities and on major roads across the country. In start, the charging infrastructure could be prioritized for Motorways M-1, M-2 and M-9 followed by M-3, M-4, M-5 and Highway N-5. Availability of charging infrastructure along major motorways and highways can ameliorate the range anxiety problem associated with EVs.

With the excess of electricity in the next few years, the government can easily set a target to reach half a million BEVs/PHEVs by 2025. As mentioned before, this requires less than 1000 MW of energy generation.

To maximize the benefits of EVs in Pakistan, a Research and Development (R&D) facility is required. This facility should pursue activities for indigenous development of technologies for EVs and its ancillary services. Beyond R&D, such facility can trigger entrepreneurial activities that have a huge potential for increasing exports.

To encourage charging infrastructure, the government may form public- private partnerships to encourage entrepreneurship in this area. Contrary to oil the charging infrastructure, such an approach requires opportunistic charging strategy. This means that, other than dedicated charging stations, the charging stations can also be installed at offices, homes, restaurants, and shopping malls etc. The charging infrastructure companies may not get a profit until sufficient EVs are in place. Therefore, tax breaks and other incentives are necessary to encourage entrepreneurship in this area.

To better manage EV charging, smart metering of EV charging stations is necessary. Electric vehicle chargers come in three levels. Level 1 charging is a slow, home based, charging that needs almost the energy of one air- conditioner and takes 8-10 hours to completely charge the battery of BEVs and half as much time to charge PHEVs. At Level 1, charging stations we propose require smart metering to better monitor and control the usage of electricity. This will ensure accurate billing and will also reduce non- technical losses. Level 2 are faster charging stations that require increasingly higher quantities of electricity with lesser charging time respectively. Such charging stations can be set up at work places or at other similar places. Level 3 charging stations are commercial charging stations that provide the fastest charging but require highest quantities of electricity.

1 Introduction

Rapidly deteriorating environmental conditions, financial deficit of the power sector and the declining economy pose grave threats to Pakistan. The situation is anticipated to further worsen in the upcoming years if significant efforts are not made to deal with the aforementioned emerging threats. Therefore, the country is in a dire need for a comprehensive strategy to be formulated and implemented to face the potent challenges.

Transport sector in Pakistan is the largest contributor towards release of Green House Gases (GHGs) into the atmosphere, which are a leading factor in rapidly diminishing the air quality index. On average, the concentration of various environmental pollutants is ten times the optimal level set by the World Health Organization (WHO) and the situation is expected to further exaggerate in the upcoming years [1]. As a consequence, the estimated number of deaths and other ailments associated with air pollution have reached an alarming scale. To put these numbers in a perspective, mortality rate due to environmental pollution far exceeds many other high profile causes of death including epidemics such malaria, tuberculosis and AIDS [1]. Hence, such emissions have manifested deleterious consequences on the health of the population. The magnitude of the problem is forecasted to increase further at an escalating pace in the near future. Hence, there is an imminent need for a solution that can solve the above mentioned predicament.

The power sector in Pakistan also faces momentous challenges. Although, the power sector in Pakistan currently fulfils the demand, it has become a severe financial burden on the plunging economy of the country. The current average demand for power is around 18,000-20,000 MW, while the system has the capacity to generate 33,961 MW [23]. Hence, there exists a gap of thousands of MW of unutilized power, which is the fundamental cause for the deficit. The capacity charge payments being made for these MW of power currently amount to billions of dollars annually. This amount is expected to multiply by many folds in the upcoming years due to an increase in the above-mentioned power gap. Such a vast deficit can potentially cripple any economic growth in future.

Pakistan's economy has been declining at an accelerating rate. A fundamental reason behind such a decline is the increasing trade deficit due to increasing imports and declining exports. Bill for fuel imports currently amounts to USD 13.3 billion, which is estimated to reach a staggering value of USD 30.7 billion by 2025, further exaggerating the already declining economy [34]. Hence, to support the deteriorating economy and to limit the accelerating trade deficit, there is a need for an immediate attention.

Introducing EVs can solve these dilemmas. EVs run on electric power instead of gasoline. Therefore, EVs do not emit harmful pollutants. Hence, replacement of FFVs with EVs can significantly reduce the emission of pollutants and so help ameliorate the disintegrating environment. EV commuters will purchase each unit of electricity from the government at a notable price tag. In such a manner, the government can not only arrange the amount for capacity payments but also earn a substantial revenue. Introduction of EVs is bound to add numerous other socio-economic advantages. EVs will limit the rising trade deficit by significantly reducing

import of fuel. Incorporation of EVs into the transportation network has the potential to introduce a whole new industry in Pakistan; creating numerous employment opportunities and adding value to the economy of the country. In the contemporary situation, EVs have become indispensable. Any further delays can exaggerate the above mentioned problems to such an extent that they can have long lasting impacts. In the upcoming sections of this report, we will provide a detailed analysis of advantages that EVs bring to the transportation network and will also provide a comprehensive framework for introducing EVs in Pakistan.

2 Transport Sector in Pakistan

The transport sector in Pakistan is growing at a double digit rate due to a number of factors [12]. The country has the highest percentage of young people in region with 64 percent of the total population below 30 years of age [2]. The overall population in the country is growing at an annual growth rate of 2.1 percent [4], [27]. Pakistan also has the highest urbanization rate in South Asia and by 2025, the urban population is projected to reach 60 percent from 40 percent in 2018 [5][6].

Currently, Pakistan is going through a rapid expansion in the network of highways (motorways and expressways). Commencement of China – Pakistan the Economic Corridor (CPEC) has revitalized the construction and rehabilitation of the network of highways under the belt and road initiative. The contemporary web of highways spans 12,131 km and is responsible for almost 80 percent of the total commercial traffic in the country [7]. By 2025, there will be an addition of 3,070 km of highway network to the already existing network [8]. Hence, in the next 7 years the network of highways in Pakistan is anticipated to proliferate by 25 percent while the total length of motorways is expected to increase by three times. Cumulatively, the aforementioned factors will add tremendous burden on the existing road network.

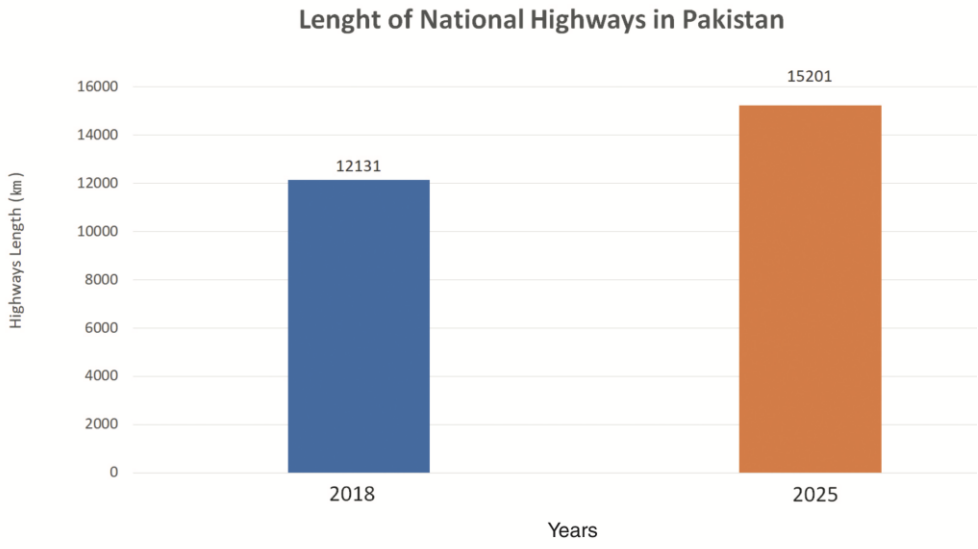
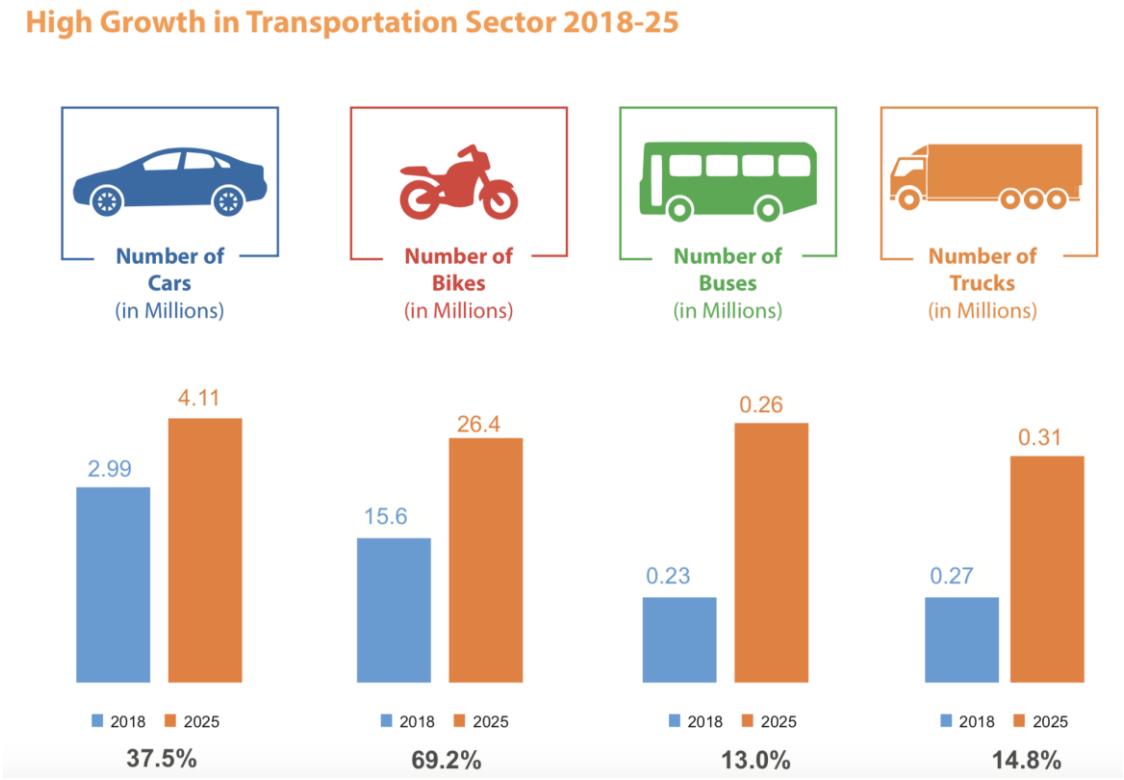


Figure 1: The magnitude of increase in the network of highways from 2018 to 2025 is substantial. Such vast and rapid expansion tends to significantly increase the vehicular transport on highways [7].

The density of cars per 1000 people in Pakistan is 16 [9]. This number is estimated to reach almost double by the year 2025. Additionally, various international automakers have also discerned such projected increase in number of vehicles. In the next several years up to 10 new automobile manufacturers have planned to install their production units in Pakistan which include Hyundai, Renault and Kia Mot-

ors [47]. Introduction of new automobile manufacturers, accompanied by an escalating expansion in the network of highways and rapid urbanization, are bound to increase the number of automobiles in the country. Presently, the total number of vehicles on roads is 19.09 million (cars, bikes, buses and trucks), of which 2.99 million are cars [10], [45]. The total number of vehicles is estimated to reach 31.8 million by 2025 with 4.11 million cars only.

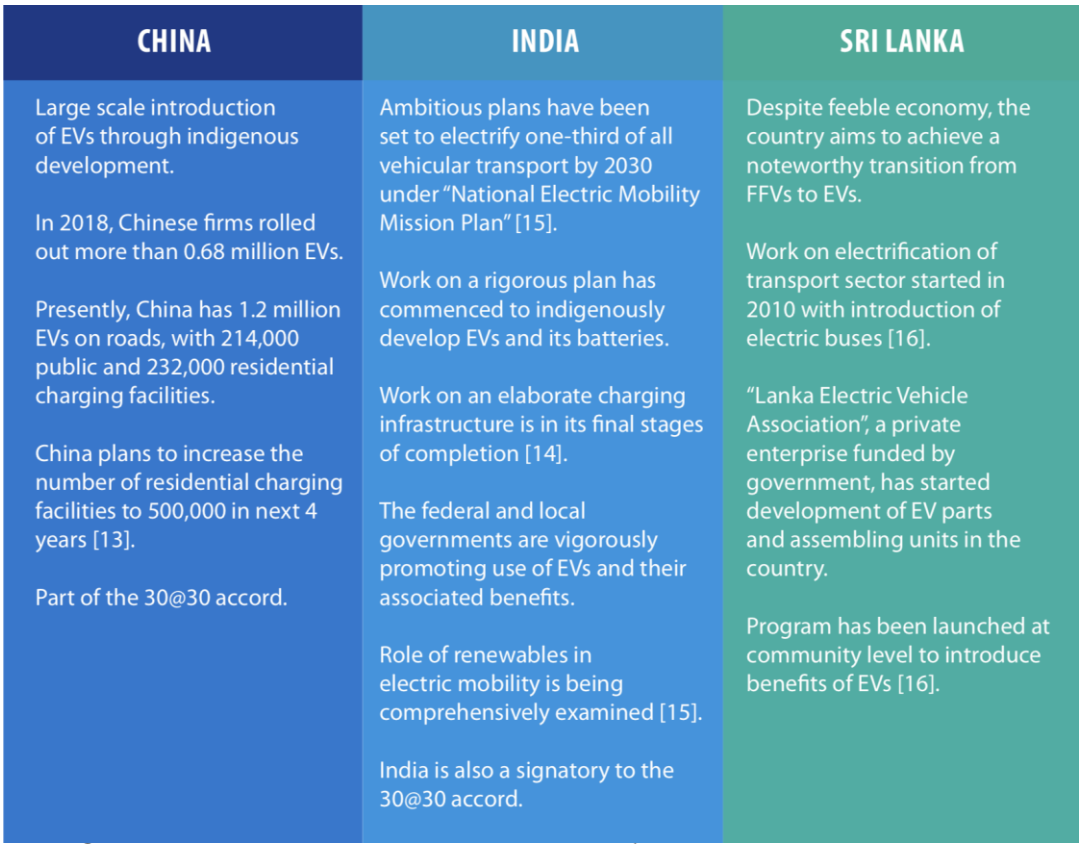
A consequence of urbanization is an increase in number of vehicles. Large cities often require commuters to travel relatively larger lengths. Hence, it requires them to utilize some kind of transportation for their daily commute which tends to increase the number of vehicles.



The ballooning transport sector will exacerbate the already compromised situation of numerous sectors. It will further deplete the already endangered environment. Additionally, it will also widen the tremendous trade deficit by significantly increase imports. The overall socio-economic cost associated with transport sector is bound to become a substantial burden on Pakistan if substantive measures are not in place.

3 | EV Targets and Estimates Around the Globe

Environmental pollution is a serious concern for earth's atmosphere and so there emerged a dire need to address the potent threat. The world has realized the significance of EVs towards a sustainable global development. Whether developed, developing or underdeveloped, many countries across the globe have set targets to incorporate a fixed number of EVs into their network of transportation over the next few years. Numerous ambitious goals have been set by the international community to achieve a transition from FFVs to EVs. According to the '30@30' initiative, many economies of world have pledged to reach 30 percent sales share for EVs by 2030 [11]. In fact, some countries have also aimed for much higher goals.



Norway and Netherlands possess significantly clean air as compared to most parts of the world. However, such countries have incorporated a sizeable number of EVs into their transportation network [39].

Introduction of EVs in the transportation grid has already been commenced by many nations worldwide. A large number of EVs currently dominate the transport sector across many countries. Surprisingly, even those nations that face the least threat from the environmental pollution have also discerned the significance of clean air and so have incorporated a considerable number of EVs.

Neighbours of Pakistan have also realized the significance of EVs. Environmental pollution in China was a well-known dilemma, which accounted for nearly one million deaths in the country [28]. Hence, to deal with the potent threat, a comprehensive strategy was formed to limit the environmental pollution through mass introduction of EVs. Similarly, India also witnessed some of the worst forms of air pollution and 14 of the world's most polluted cities were once located there [40]. To deal with such magnitudes of air pollution, the Government of India has launched an aggressive plan to achieve partial electrification of its transport sector. Even Sri Lanka, with its meagre economic resources, has embarked on an ambitious plan to achieve a substantial transition from FFVs to EVs.

Such efforts by India, China and Sri Lanka Depict highest levels of resolve to decarbonize the environment. Efforts to limit environmental pollution has translated into numerous quantifiable advantages for these countries. $PM_{2.5}$, the most detrimental component of the air pollution, concentrations were recorded in Beijing to be 54 percent less in 2017 when compared to the same time in the year 2016 [17]. Reduction in concentration of environmental pollutants resulted in estimated 47,000 fewer deaths in China and added 710,000 years of additional lifespan (when compared with the situation in 2013) for people in 74 cities across China that were surveyed [18].

Determined efforts by the Indian government have yielded substantial results and the country is now on track in achieving an ambient air. $PM_{2.5}$ concentration in New Delhi declined from 153 $\mu g/m^3$ in 2016 to 120 $\mu g/m^3$ in 2018 [19]. Similarly, PM_{10} concentrations in India are also diminishing. On average across India, PM_{10} concentrations were recorded as 289 $\mu g/m^3$ in 2016, which declined to 268 $\mu g/m^3$ in 2017 [20]. Reduction in environmental pollution in India will directly translate into numerous socio-economic advantages. It is well estimated that with the current efforts to reduce environmental pollution in India, 64,000 premature deaths will be averted up till 2040 [21]. Additionally, due to the relentless efforts in India to curb environmental pollution, the rate of increase of exposure to environmental pollutants has decreased by 9 percent [21].

In Pakistan, environmental pollution is not a threat, instead its adverse effects can be easily quantified. Despite having one of the most polluted air in world, there exists no strategy to limit the emission of pollutants from the transport sector. The air quality index in the country is so abysmal that it has crossed the safe limits by many folds. Therefore, Pakistan NEEDS even a more ambitious plan to limit environmental degradation and introduction of EVs in Pakistan can potentially be a substantial component of this plan.

4 Power Sector

4.1 Present and Future Electricity Demand and Supply Scenarios

Contrary to the common perception, Pakistan has the capacity to produce much more energy than its demand. To qualify this statement, we would like to refer to the figure below.

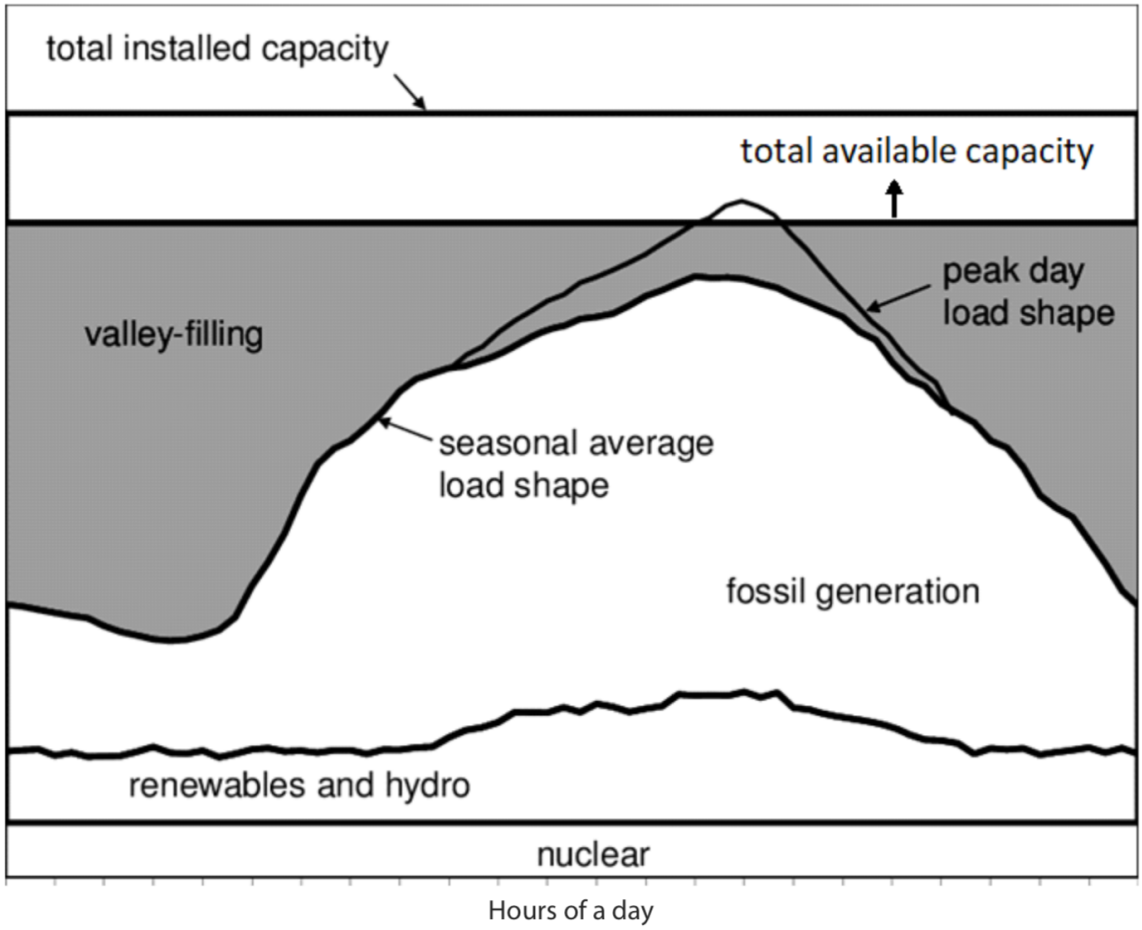


Figure 3: *The load curve for power and the available capacity of the system [3].*

The total seasonal load is generally well below the total available capacity. The only problem here is that for very few hours in summers, the load slightly exceeds the available capacity. However, for this issue, we have proposed a solution in the subsequent sections of this report. The gray region on both sides of the seasonal average and peak day load curve represents the difference between the capacity of the system and the load, where the load is substantially below the total available capacity. This vast gray region represents the hefty capacity payments.

The total power generation capacity of Pakistan in 2018 is 33,961 MW while the maximum demand during the year has been reported to 25,227 MW[23]. However, the

average demand during both the seasons, winters and summers, is substantially lower than the highest demand recorded in a typical year. A significant portion of the total power producing capacity (18,137 MW) comes from the Independent Power Producers (IPPs) which utilize natural gas, furnace oil and coal to produce electricity. Such power plants deliver the energy at the highest financial cost. The difference between the contemporary demand (25,227 MW) and the capacity (33,961 MW) is 8,734 MW. This energy gap is expected to further widen in the upcoming years as many new power generating units are planned to be inducted into the power generating grid of Pakistan.

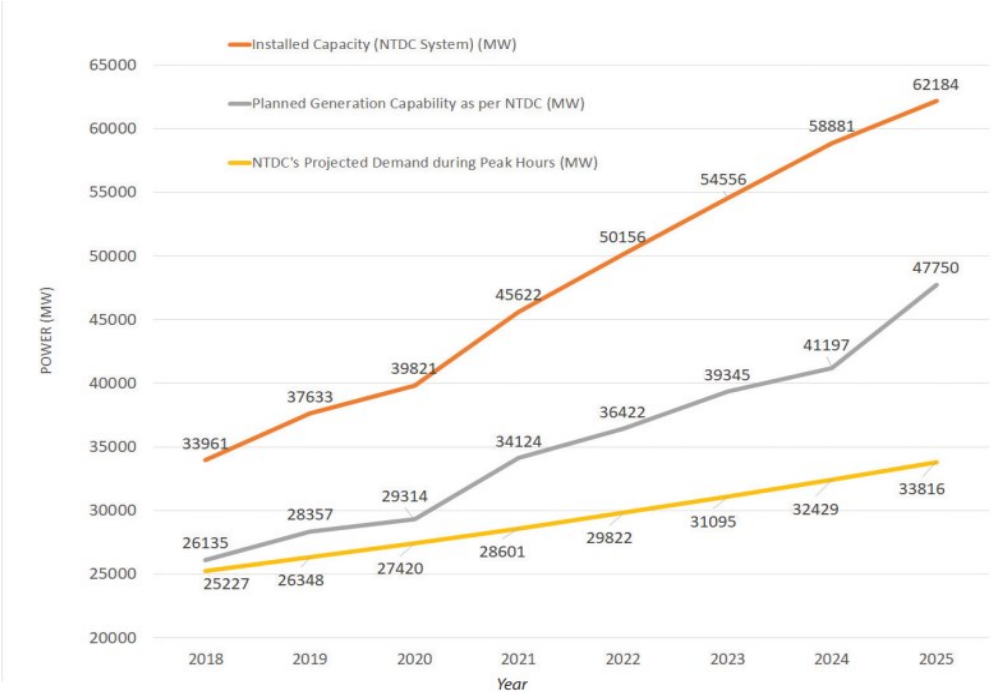


Figure 4: The contemporary and the projected power demand, capacity and the planned generation capability in Pakistan till 2025 [23].

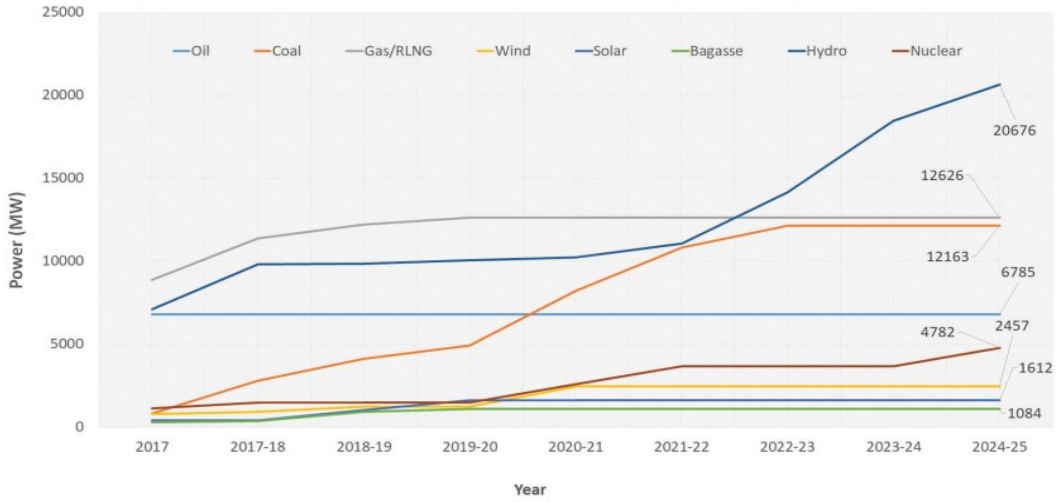
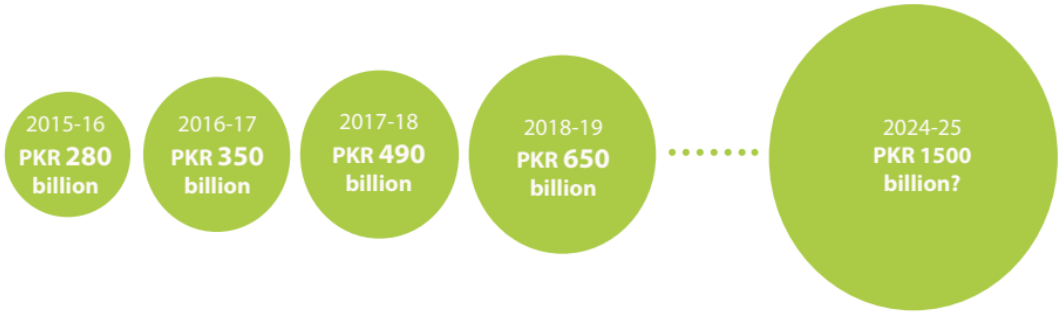
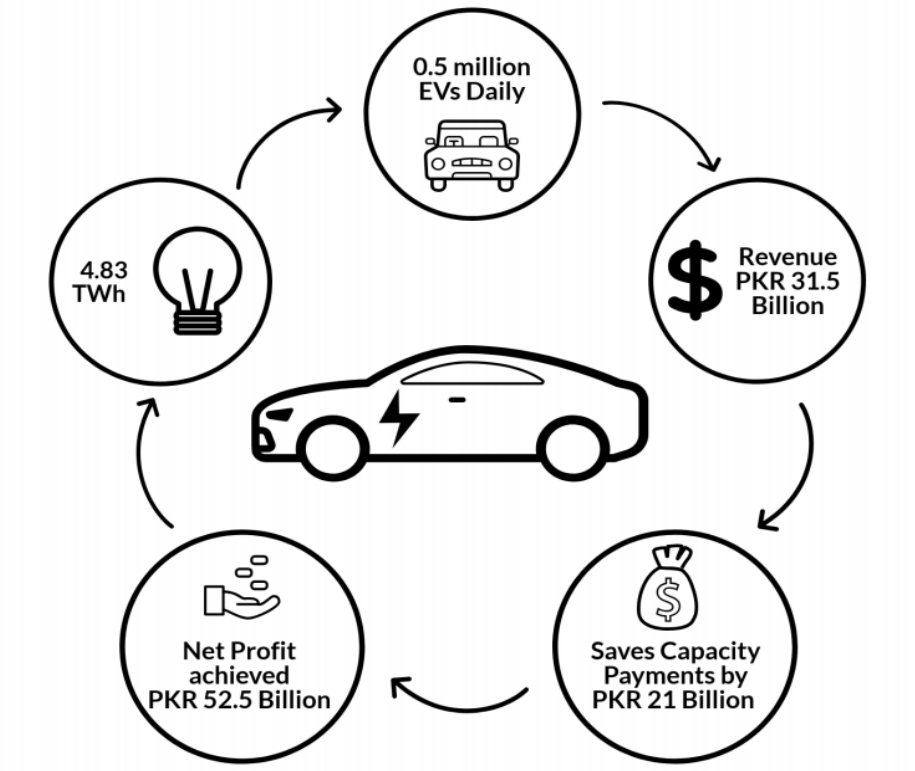


Figure 5: Present and future generation capacity of various energy resources in Pakistan till 2025 [24].

The ability of the system to produce excess energy than the demand comes at a grave financial cost. A hefty capacity charge payment has to be paid to the power producing units. Such capacity charge payments for the current fiscal year amount to more than PKR 490 billion and are expected to reach PKR 1500 billion by 2025 [25].The government pays the capacity charge payments at PKR 4.56 for each unit of electricity that the system has capability to generate but does not generates due to fulfilment of demand [25]. Such capacity payments have become a severe financial burden on the economy of the country and are one of the fundamental reasons for the colossal circular debt of the power sector in Pakistan. Hence, there is a dire need for a solution to reduce the size of such capacity payments.

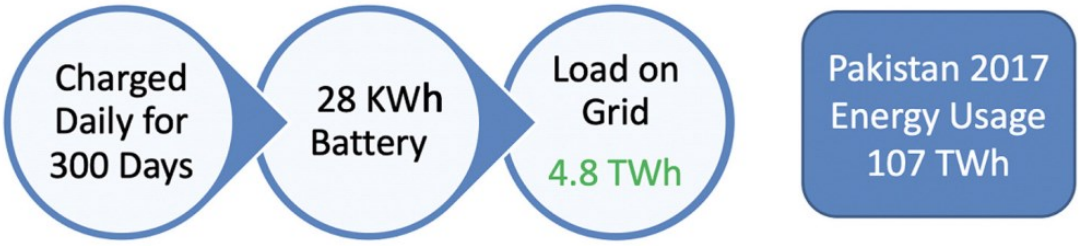


Pakistan has 42 TWh of unutilized energy. From this unutilized energy, 4.83 TWh can be used to charge half a million EVs, which can bring capacity payments down by PKR 21 billion. Additionally, it will generate a revenue of PKR 31.5 billion with a net profit of PKR 52.5 billion to the economy.



4.2 Effect of EVs on Grid Load

We suggest bringing 0.5 million EVs into the transportation grid by 2025. Using very realistic numbers and most accurate estimations, the effect of proposed number of EVs on the national electricity load will be as follows



Estimated effect on the load by adding 0.5 million EVs.

According to our estimates as per the context of Pakistan, each EV will require 28 KWh of energy per day. The daily energy consumption for 0.5 million EVs will be 16,100 MWh after transmission and other losses have been taken into account. Each EV can approximately travel 150-300 Km on a single charge. Therefore, each EV may not require daily charging, specially for intra-city commuters. Hence, if we assume each EV charges for 300 days in a year, then the total energy required by all EVs in a year will be 4.8 TWh, whereas the annual energy requirement of Pakistan was 107 TWh in 2017. Summing up the aforementioned energy requirements into a perspective, the load of half a million EVs will be approximately equal to the load of adding 1.36 million new residential air conditioners.

5 Impact of Energy and Transport Sector on the Environment

Energy and transport sectors are the primary contributors towards deteriorating environment in the country. Exhaust fumes from tail pipe emissions of vehicular transport and emissions from power plants have depleted the environment to such an extent that concentrations of harmful pollutant particles in the air are multiple times higher than the safe limits. As a consequence, many metropolitan areas of Pakistan has been ranked as one of the most polluted regions of the world. Smog has engulfed many cities of Pakistan. It is a type of air pollution released due to combination of air pollutants, such as Carbon Dioxide, Sulphur Dioxide and Oxides of Nitrogen, with the moisture in the air. The WHO suggests an ambient PM level; 30 µg/m^3 for $PM_{2.5}$ (fine particles with diameter no larger than 2.5 µm) and 20 µg/m^3 for PM_{10} (particles with diameter between 2.5 µm and 10 µm [41], [42]. According to data, the concentration of the PM reported in Lahore by Pakistan Environment Protection Agency (Pak-EPA) far exceed the safe limits. The environmental degradation has become so severe in Pakistan that the two largest cities of Pakistan, Lahore and Karachi, have been ranked among the top 10 most polluted cities in the world [46]. The transport and energy (power) sectors in Pakistan have the largest share in depleting the environment.

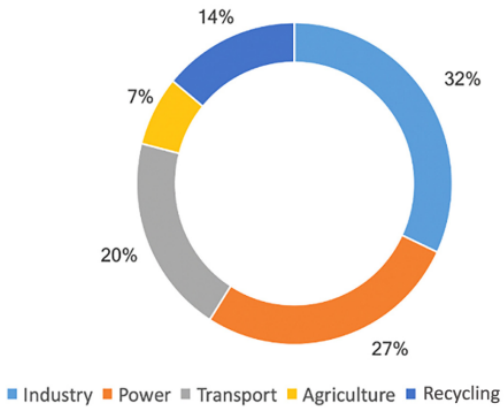


Figure 6: Share of some of the key sectors of economy in releasing Oxides of Nitrogen, NOx, into the atmosphere. Transport sector is the largest contributor of compounds of nitrogen, such as nitrogen dioxide, into the atmosphere [26].

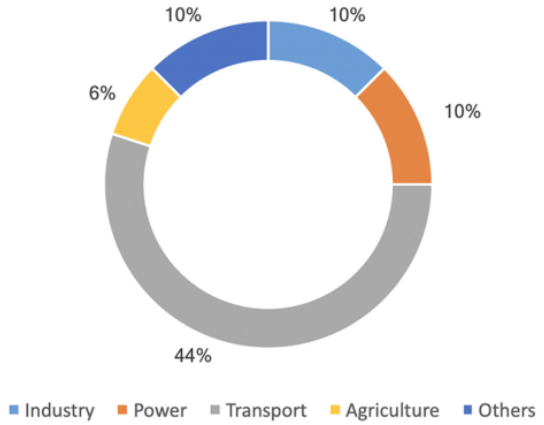


Figure 7: Share of some of the key sectors of economy in releasing Carbon Dioxide, CO2, into the atmosphere. Transport sector is the third largest contributor in releasing Carbon Dioxide into the atmosphere [26].

Concentration of Nitrogen Dioxide, one of the most detrimental elements of the vehicular emissions, has reached a staggering level. The concentration of NO2 has reached more than 0.35 Dobson across many cities in Pakistan, while the optimal limit is 0.07 Dobsons.

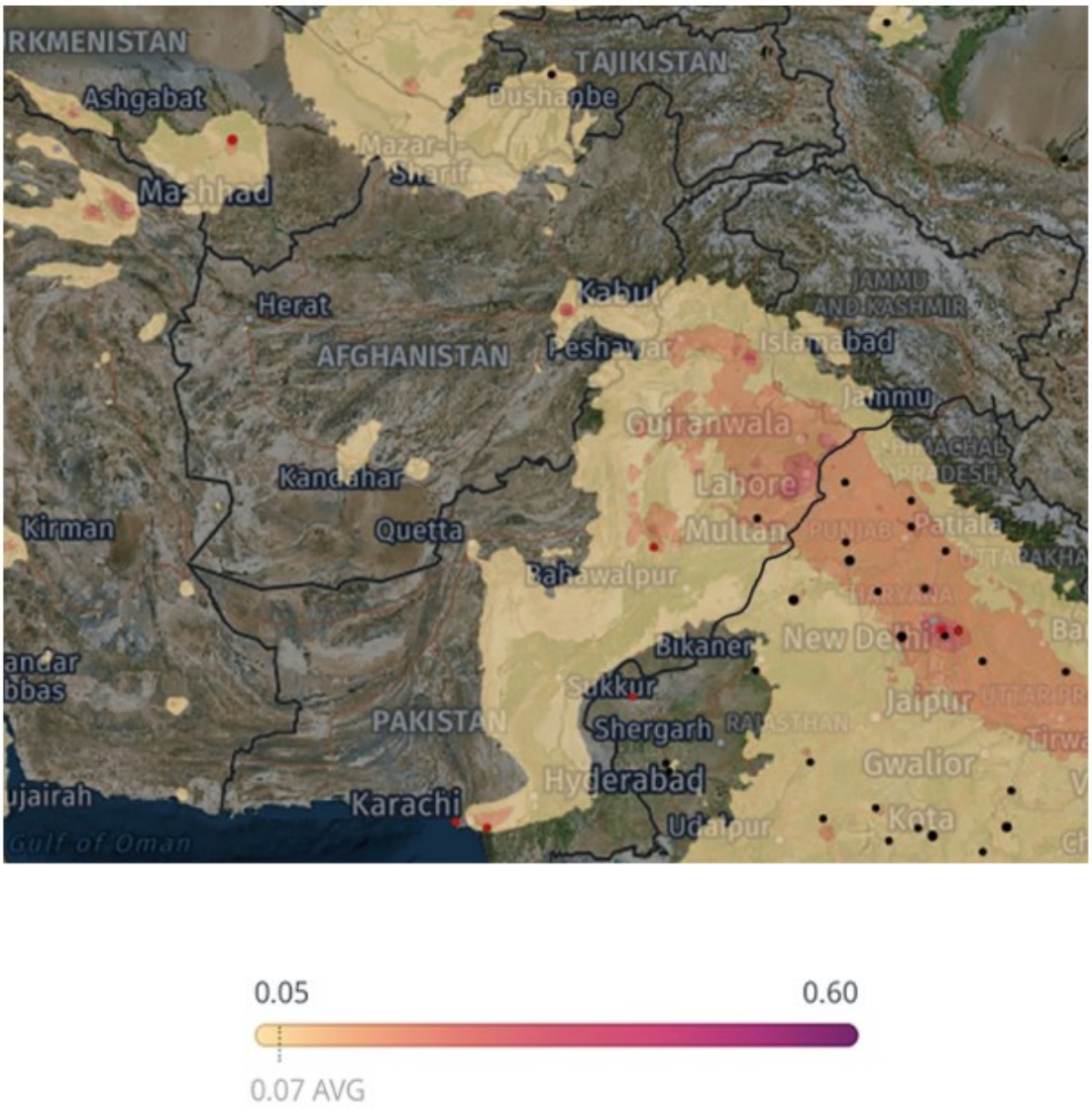


Figure 8: The concentration of NO_2 across various regions in Pakistan [43].

Concentration of $PM_{2.5}$ is also no surprise. Significantly higher quantities of $PM_{2.5}$ in the atmosphere in Pakistan have become a critical health concern for the people and with the expansion of transportation network, such numbers are anticipated to further exaggerate.

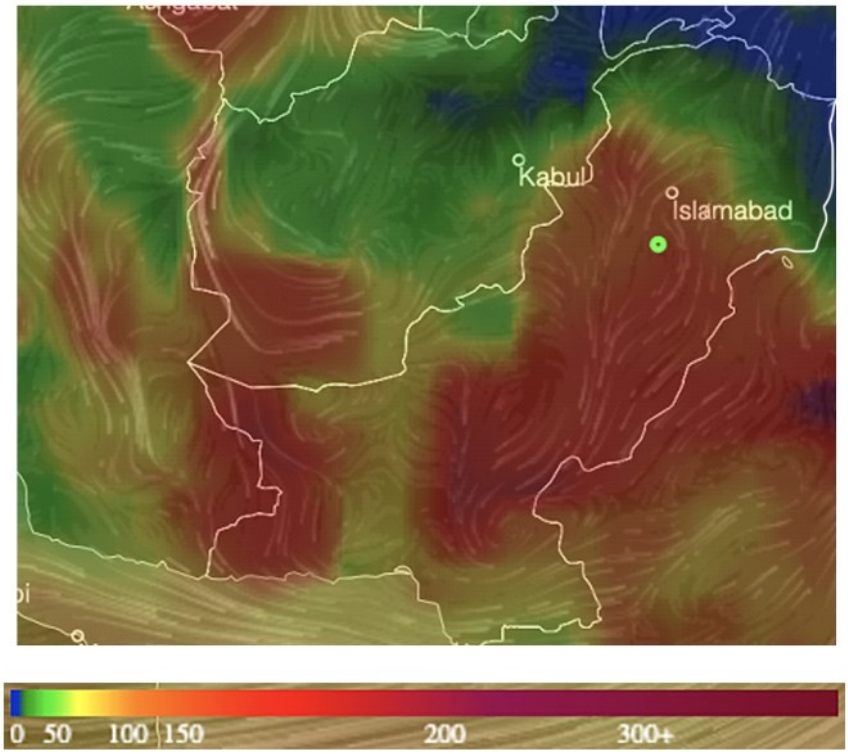


Figure 9: Concentration of $PM_{2.5}$ across various regions in Pakistan [30].

Likewise, the concentration of PM10 has also reached a critical level in Pakistan.

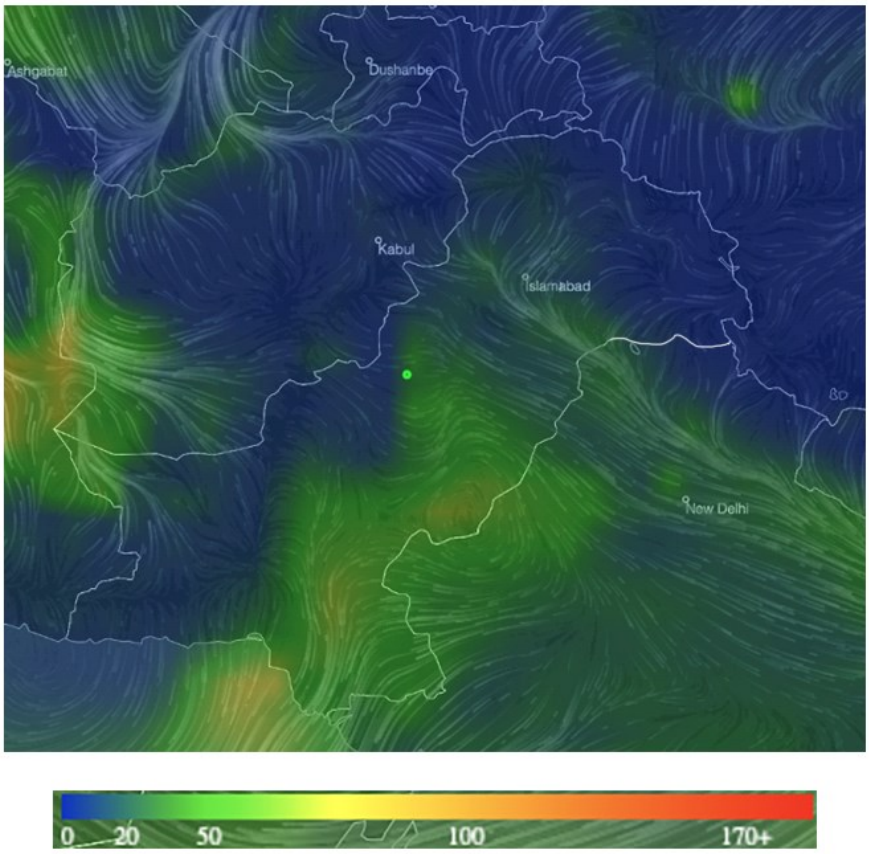
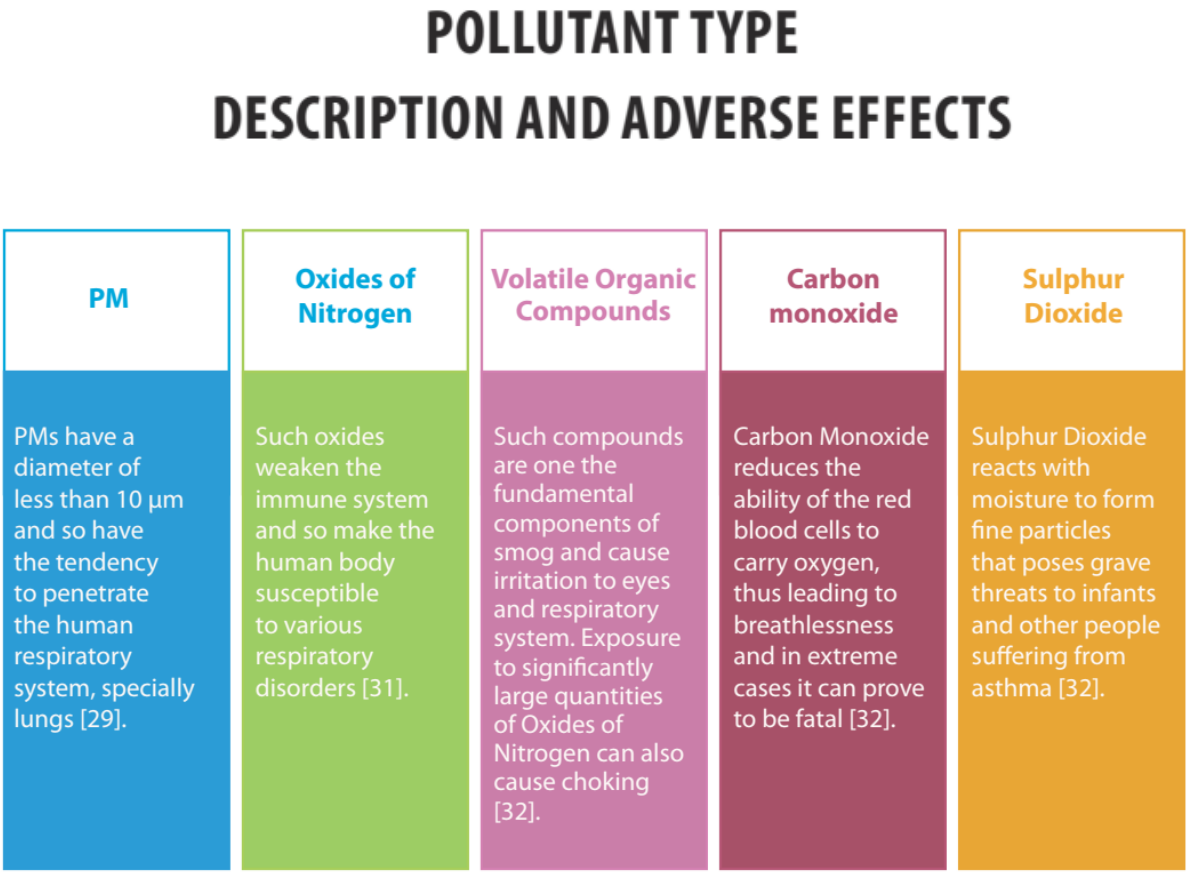


Figure 10: Concentration of PM_{10} across various regions in Pakistan [30].

Such critical quantities of environmental pollutants in the air in Pakistan have accounted for more than 310,000 deaths, while many times more people suffer from respiratory disorders [44].



The transport and energy sectors in Pakistan have become the leading contributor towards environmental deterioration and needs to be addressed with utmost priority. If the situation continues to exaggerate with the ongoing rate, then the environmental pollution has a great tendency to become the leading cause of mortality in the country.

6 Socio-Economic Cost of Transport Sector in Pakistan

Pakistan has to endure a substantial socioeconomic cost for its transport sector. Such cost includes escalating bill for fuel imports, economic burden of carbon, Sulphur and Oxides of Nitrogen.

Hefty bill for the import of oil is one of the leading factors in escalating trade deficit of the country. Presently, Pakistan imports oil worth of USD 13.3 billion [34]. If the transport sector continues to expand at the present rate then the bill for fuel imports is expected to rise up to USD 30.7 billion, putting further pressure on foreign payments.

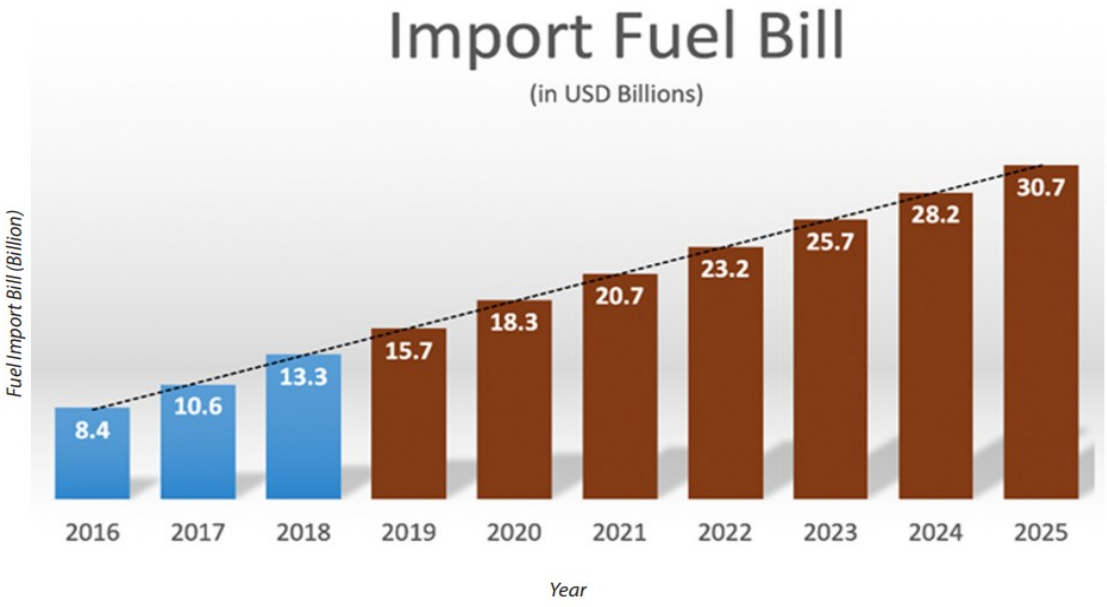


Figure11: Present and anticipated bill for fuel imports in Pakistan [34].

In the next few years, each metric ton of pollutants released in quantities higher than a fixed threshold will result in taxes paid by the government to the international community. Since, the transport sector of Pakistan is the leading contributor towards release of such environmental pollutants so by introducing EVs in the country, such colossal amount in form of taxes can be saved.

Introduction of 0.5 million EVs in Pakistan by 2025, has the tendency to limit Carbon Dioxide emissions by 1.47 billion kg /year. Each metric ton of CO 2(1000 kg) will approximately cost USD 15 [22]. Similarly, the price tag for the release of oxides of NO_2 and SO_2 is approximately USD 175 and USD 2.81 respectively [37]. If we bring half a million EVs on roads in Pakistan, then the total amount of carbon tax saved will be USD 22.1 million. Additionally, it will also prevent release of 1.96 million kg/year of NOX and 93 thousand kg/year of SO2 respectively. Since, EVs utilize electric power rather than gasoline, so half a million EVs on roads by 2025 will reduce the bill for oil imports by USD 504 million and save up to 681 million litres of imported oil. Additionally, taking an average traversing distance to be 25,000 km per year, each FFV costs PKR 127,000 more than an EV due to its fuel consumption. By just introducing half a million EVs, USD 470 million can be saved

in term of gasoline usage.

Introducing EVs in Pakistan will establish a whole new industry. Indigenous assembling or manufacturing of EVs has the potential to add hundreds of thousands of employment opportunities and so reduce the significantly high unemployment rates. The most substantial contribution of EVs will be reduction in tail pipe emissions from vehicular transport which will directly translate into improved air quality. An ambient air will in return translate into improved health of the people across Pakistan.

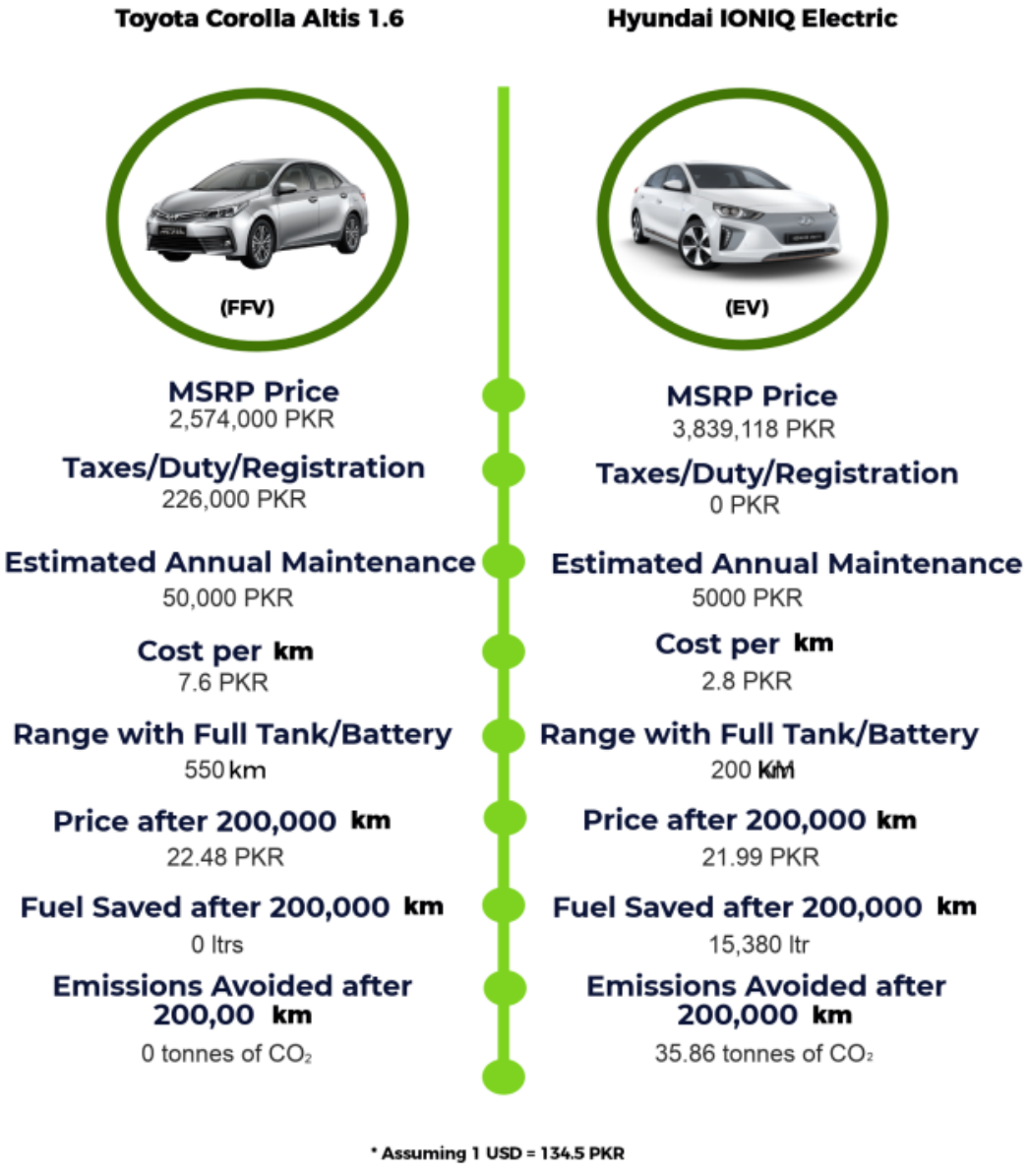
Unlike FFVs, which require an elaborate supply and demand mechanism for delivering gasoline at fuelling stations, EVs do not require any such elaborate network. Almost all regions in Pakistan are being supplied with adequate power from the national grid which will be sufficient to set up charging facilities for EVs.

EVs have huge tangible benefits which have been illustrated in this report. However, even more benefits of EVs are intangible such as impact on the health of the population and numerous resources saved due to better health.

7 EV VS. FFV Comparison

Initially, an EV costs more than an FFV due to its higher price tag. However, in the long run EV's cost becomes comparable to its similar FFV. This is due to a number of factors such as minimal maintenance cost, less duties, cheap price of electricity and so on. According to our estimates, after both the cars have been driven for 200,000 km, an EV costs less than its similar FFV. Additionally, in the next few years, the purchase price of EVs is expected to decline further which will make EVs even a more economically viable option in a lesser period of time.

Keeping in view the present sale price of an EV (Hyundai Ioniq) and its similar FFV (Toyota Altis), we have provided a comparison illustrating how an EV is an economically viable option as compared to a similar FFV.



Chargers for EVs

Level 1 Charger

- 120V/1.4kW-3.3kW power rating
- Full charge: 10 to 20 hours
- For home and workplaces

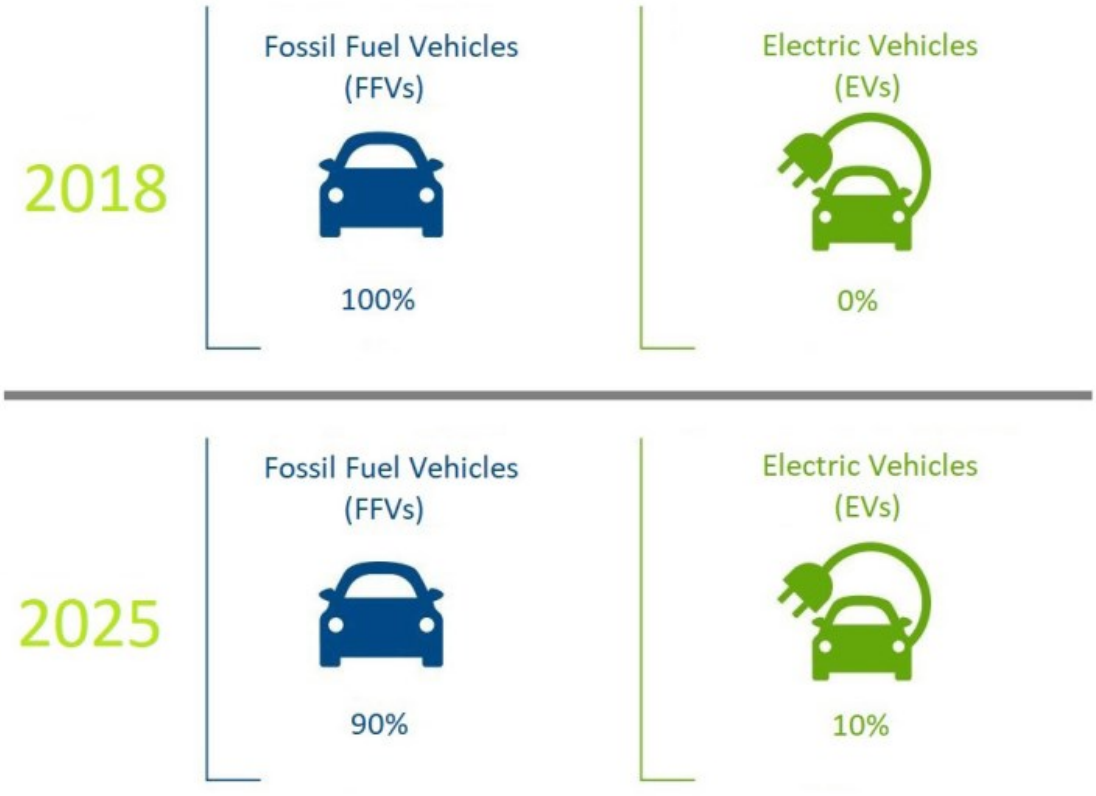
Level 2 Charger

- 240V/5.0kW-19.2kW power rating
- Full charge: 4 to 8 hours
- For home, workplace, and public settings

Level 3 /DC Fast Charger

- 200-500V/50kW-120kW or more power rating
- Full charge: 20-30 minutes
- For commercial use only

Penetration of EVs in Pakistan



8 Results from the Simulators

As a part of this report, we have designed three simulators which calculate the load due to addition of a number of EVs, the effect of the EV load on the power grid and the comparison of running cost of EV vs. FFV over a span of several years. These simulators are available at the companion website of this report at the following URL: http://web.lums.edu.pk/~eig

Simulator 1: EV Load on the Grid

In this simulator, the user can select a number of vehicles as per discretion. The user also has the leverage to choose in how much time does he wants to completely charge an EV. Additionally, the user can select the power in KW for the charger with which an EV has to be charged. Corresponding to the number of hours in which the user wishes to charge the vehicle, the time of the day can be selected in which the charging is to take place. Transmission and EV charging losses can also be set as per discretion of the user. Once all these parameters have been selected by the user, the simulator then calculates the load of charging respective number of EVs. The effect of the additional load due to EVs is then compared by the total national load. The simulator distinguishes the load with and without EVs. The layout of the simulator is as follows:

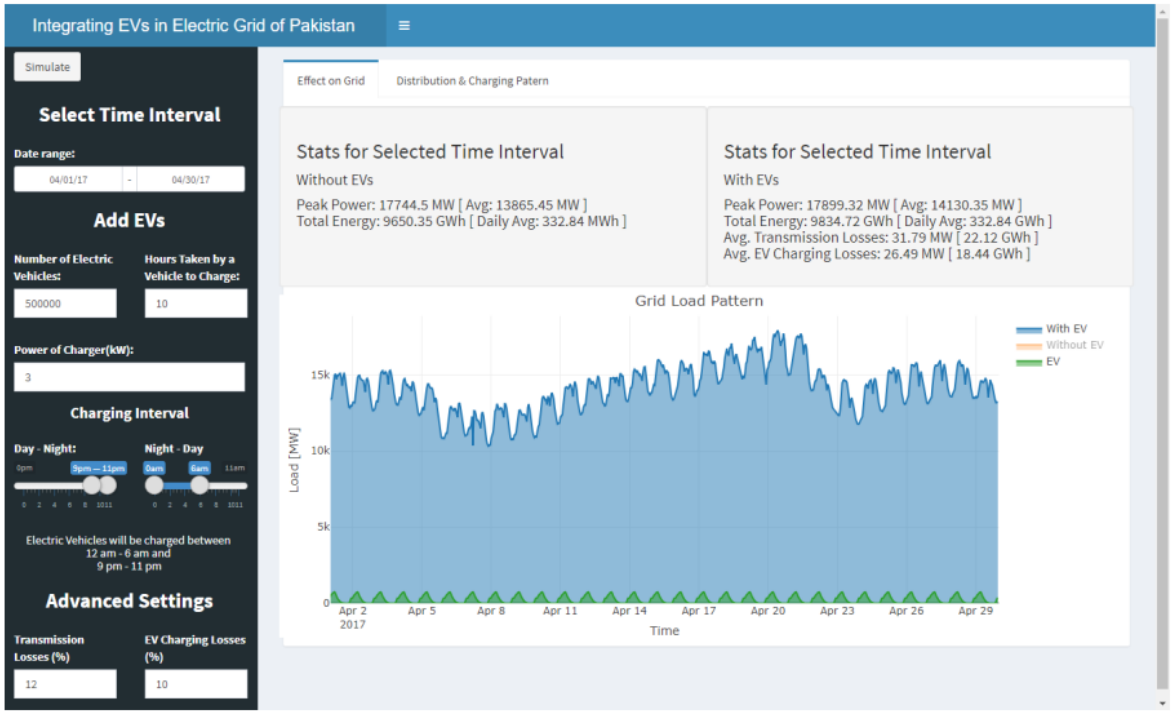


Figure 12: EV load on the Grid Simulator

Simulator 2: EV vs. FFV Cost Comparison:

This simulator calculates the cost per km of EV and its equivalent FFV. Once the desired input, specially the number of kilometres driven have been selected, the simulator calculates the price of both types of vehicles.

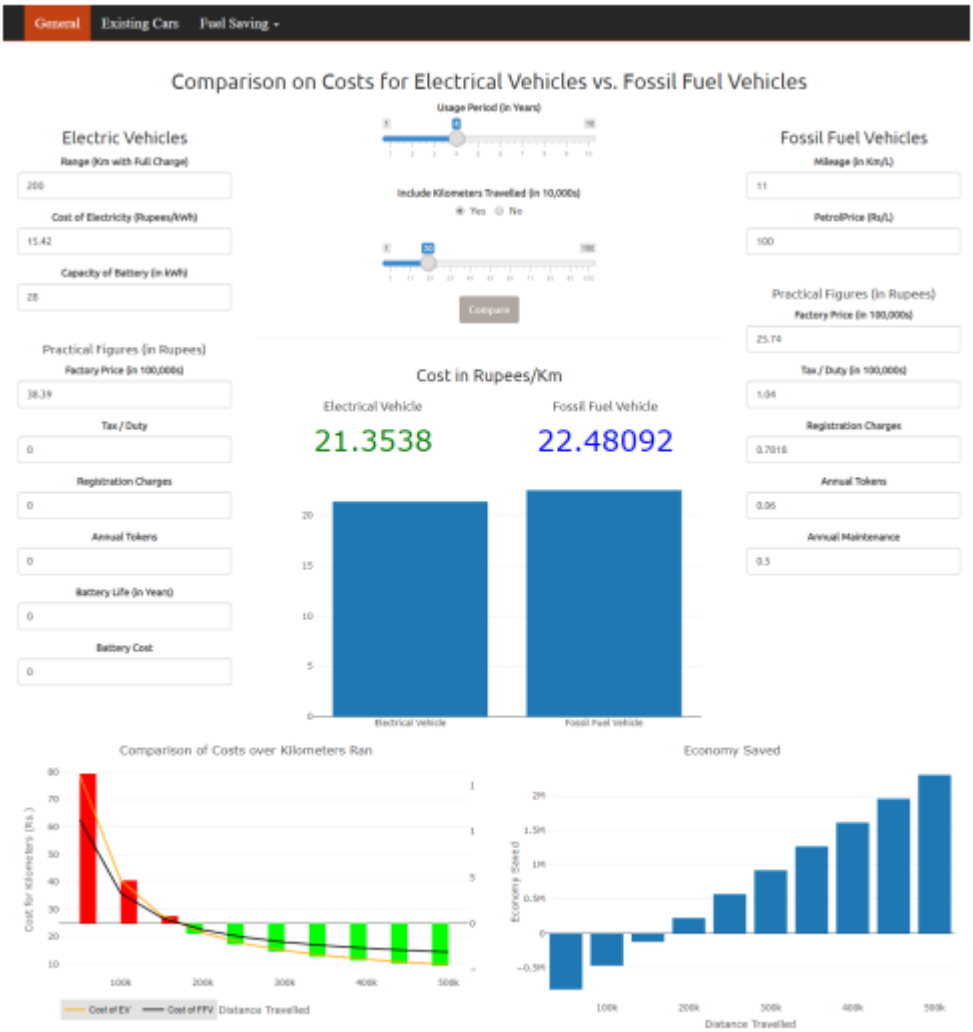


Figure 13: EV vs. FFV Cost Comparison Simulator.

Simulator 3: Fuel Saved by EVs

This simulator calculates the effect on the national load due to addition of a variable number of cars, busses, bikes and trucks that solely run on electric power. Once the user has selected the parameters, the simulator calculates and graphically illustrates the load due to each type of transport. The simulator also represents fuel saved due to utilization of electricity by addition of desired number of EVs.

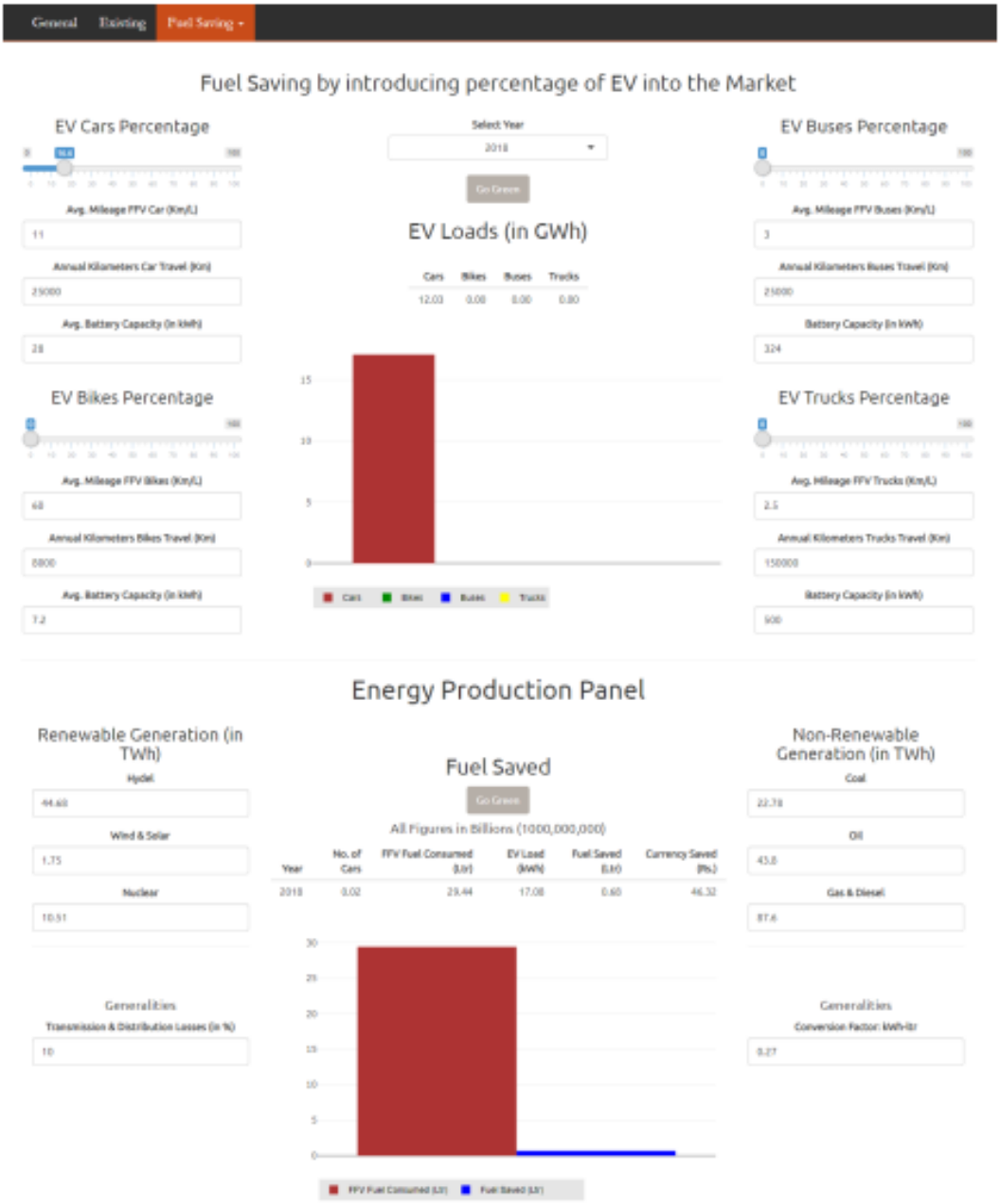


Figure 14: Fuel Saved by EVs Simulator

9 Policy Recommendation

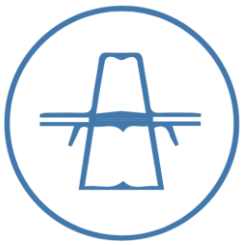
While the running cost of EVs is one third of FFVs, the capital cost is quite high. Therefore, we propose that the duty and taxes on EVs should be reduced to a total of 5 percent. The price of EVs is expected to decline the next few years and become comparable to FFVs. As the price for EVs decline, the current tax abatement at a total price of 5 percent, can be decreased. It implies a gradual increase in tax on EVs as price for EVs decline. In such an approach all the respective government agencies and ministries need to be on the same page to formulate a coherent strategy that can incentivize the introduction of EVs in the transportation grid of Pakistan. Initially, the government can give tax relaxation to CBUs, which are the cars imported into Pakistan, since, it will not be possible to commence indigenous development of EVs in a very short period of time. However, by 2020-21 this exemption should only be offered to CKDs units, which will be assembled indigenously so as to encourage the local automakers to manufacture EVs in Pakistan. As explained in the report, the savings from energy efficiency of EVs can repay these taxes in other forms such as fuel savings and reduction in oil import bill, not to mention the environmental savings that results from lesser emissions. Additionally, provinces should also be encouraged to reduce registration fees and token taxes on EVs.

We propose that the tax relaxation should also be offered to PHEVs since they offer a mix of both EVs and the FFVs. At the beginning of introduction of EVs in Pakistan, an elaborate charging framework will not be present which will limit the driving range of EVs and so discourage people from achieving a transition from FFVs to EVs. Hence, by utilizing PHEVs this problem can be solved. When the commuter believes that the battery of an EV requires charging, but when there is no immediate charging facility nearby, then in such a situation, the car has the ability to run on gasoline. In such a manner the 'range anxiety' problem can be overcome.

With the excess of electricity in the next few years, the government can easily set a target to reach half a million BEVs/PHEVs by 2025. As mentioned before, this requires less than 1000 MW of energy generation. The proposed half a million EVs will require 4.8 TWh of energy annually, whereas the total energy demand in the country is 107 TWh presently. Hence, half a million EVs will only add a minimal burden on the load. Such additional load will be completely manageable keeping in view the power producing capacity of the system which is significantly more than the present and forecasted load.

To better manage EV charging, smart metering of EV charging stations is necessary. Electric vehicle chargers come in three levels. Level 1 charging is a slow, home based, charging that needs almost the energy of one air-conditioner and takes 8-10 hours to completely charge the battery of BEVs and half as much time to charge PHEVs. At Level 1, charging stations we propose smart metering to better monitor and control the usage of electricity. This will ensure accurate billing and will also reduce non-technical losses. Level 2 are faster charging stations that require increasingly higher quantities of electricity with lesser charging time respectively. Such charging stations can be set up at work places or at other similar places. Level 3 charging stations (DC fast charging stations) are commercial charging stations that provide the fastest charging but require highest quantities of electricity.

To encourage charging infrastructure, the government may form public-private partnerships to encourage entrepreneurship in this area. Contrary to oil the charging infrastructure, such an approach requires opportunistic charging strategy. This means that, other than dedicated charging stations, the charging stations can also be installed at offices, homes, restaurants, and shopping malls etc. In the early phase of introduction of EVs in the country, the companies developing charging infrastructure may not have a substantial number of customers due to a small number of EVs. Hence, to incentivize charging infrastructure, the government can offer incentives in the form of tax exemption to the company developing charging infrastructure. This tax exemption can be removed once a sufficient number of EVs have been incorporated into the transportation network in Pakistan.



The charging infrastructure may need to be in place at major cities and on major roads across the country. In start, the charging infrastructure could be prioritized for Motorways M-1, M-2 and M-9 followed by M-3, M-4, M-5 and Highway N-5. Availability of charging infrastructure along major motorways and highways can ameliorate the range anxiety problem associated with EVs.

To maximize the benefits of EVs in Pakistan, a R&D facility is required. This facility should pursue activities for indigenous development of technologies for EVs and its ancillary services. Beyond R&D, such facility can trigger entrepreneurial activities that have a huge potential for increasing exports.

10 Suggested Role of Federal/Provincial Ministries and Government Agencies in Developing EV policies

The most fundamental aspect in producing a conducive environment for incorporation of EVs will be an efficient planning and coordination among various governmental departments and ministries. The aim will be to introduce those policies that incentivize commuters to transition from FFVs to EVs. Therefore, there needs to be a strong agreement between all the respective governmental entities so that the policies of one entity are not in conflict with those set by the other. The key ministries and departments with their proposed role in introducing EVs are as follows:

Planning Commission

The Planning Commission is the main planning body at the Federal level. It is direly needed that EV targets become a part of the five years' plan. Planning Commission should prioritize projects that help the country reach its EV penetration targets.

Federal Board of Revenue and the Ministry of Finance

FBR and the Ministry of Finance need to work in conjunction to implement a planned reduction on taxes and duties for EVs. There is also a need for a policy that incentivizes EVs through limiting registration cost, import duties and yearly token tax. Some of the incentives falls under the purview of provincial ministries of revenue. Therefore, the polices of provincial ministries should also follow the overall EV policy framework.

Ministry of Energy (Power Division)

Globally, the electrification of energy is on the rise. EVs are no exception where the energy is transformed from primary sources of oil and gas to a secondary source of electricity. This electrification gives an opportunity to set targets for addition of further renewable energy into the energy grid of the country. This will ensure reduction in emissions for each mile travelled on EVs.

The Ministry of Energy along with other entities of the government must also start working towards R&D center for EV Transportation. This center should work towards encouraging local R&D and manufacturing of EVs. Unlike FFVs, the technology of EVs is very simple and it should be much easier to manufacture them locally when compared to FFVs.

Ministry of Commerce, Trade and Industry

There is need for short, medium and long term policies for CBUs, SKDs, CKDs and local manufacturers with eventual aim for indigenous manufacturing of EVs. The respective ministry also needs to specify EV types, models and other options that will be introduced. Various incentives for developing infrastructure for charging and battery replacement also need to be planned out.

Ministry of Climate Change

Ministry of Climate Change needs to incorporate EVs into the climate policy of the country. The concerned ministry also needs to identify the most optimal way to introduce EVs, while at the same time maximize their environmental advantage.

Ministry of Communications

The respective ministry needs to identify optimal charging locations on motorways and highways to efficiently address the range-anxiety problem. The concerned ministry should also implement plans identifying future charging locations across the country.

Metropolitan Corporations/ Development Authorities.

Metropolitan Corporations and Development Authorities of all major cities in Pakistan need to formulate a conducive policy for facilitating public and private charging infrastructure along with reduction in taxes and other charges on such facilities.

National Transmission and Dispatch Company (NTDC)

NTDC is the responsible body for making energy forecast and subsequent generation planning for the country. NTDC should include the EV targets in its generation and plan to see if newer generation resources are needed down the line. Moreover, NTDC is also responsible for specifying standards for smart metering. Smart metering standards for all levels of charging infrastructure must be created so that DISCOs meter the charging stations according to nationally specified standards.

Distribution Companies (DISCOs) and K-Electric

Distribution Companies (DISCOs) and K-Electric need to manage load forecasting for EVs and demand side management for EVs and using EVs. There is also a need for providing load for level 2 and 3 charging stations under their jurisdiction. Smart metering for EVs, especially for Level 2 and Level 3 charging stations, must be provided so as to minimize non-technical losses in EV charging.

NEPRA

There is a need for formulating a policy to enact EV tariffs and to ensure compliance with EV standards and specifications. The foremost of which are safety standards for EVs. Another role that NEPRA must take on is specifying the standards and specifications of charging stations. EVs and charging station standards will make sure that quality products are available in the country.

Banking Sector

The State Bank of Pakistan (SBP) has launched Green Banking Guidelines (GBG) to support sustainable and green development in Pakistan. The GBG aims to mitigate environmental risks and instructs banks under its jurisdiction to stringently follow the guidelines. However, GBG does not addresses EVs [33]. We propose that SBP should plan a policy that should provide financial support for potential EV purchasers. The policy can include reducing rate of interest on loans intended to purchase EVs. An important aspect for such loans will be to provide relaxation on the amount of instalments and also increasing the time limit to repay the amount.

11 Conclusion and Future Work

Our goal is that this EV recommendation report kick starts the efforts towards EVs in Pakistan. In this report, our focus was on electric cars. But there are other road transportation types in Pakistan as well, including two and three wheelers, buses and trucks. All these types of vehicles require different strategy due to the nature of their usage. Two and three wheelers are typically used within a city and could be charged from ordinary wall socket. On the other hand, buses and trucks typically cover longer distances so their introduction requires a completely different strategy. Our next report, which will be an addendum to this report, will focus on these types of transportation.

One of our projects is also looking at electrifying the road transportation in the Northern Areas of Pakistan. Because of CPEC and increasing transportation, the glaciers in the Himalayas and Karakorum region are under severe threat. An all-electric fleet of road transportation will help reduce the environmental impact on these glaciers. Hydropower is abundantly available in the Northern region throughout the year and this energy could readily be used in charging EVs. This not only eliminates the road transportation emissions but also will improve the volume of road transportation.

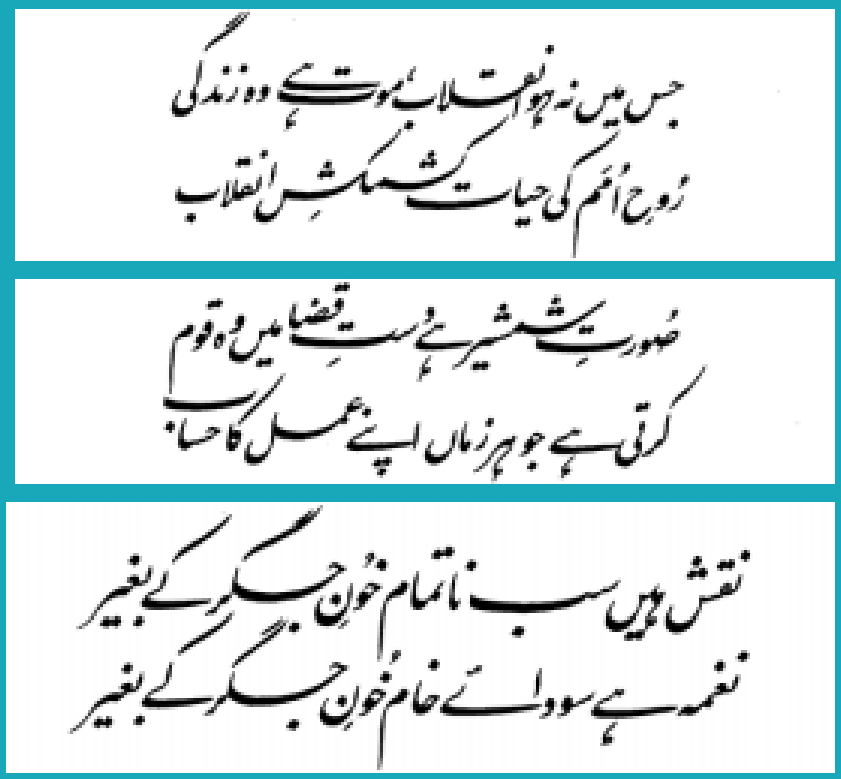
References

[1] Akbar, S., and K. Hamilton. 2010. "Assessing the Environmental Co-Benefts of Climate Change Actions." World Bank Group, 2010 Environment Strategy, Analytical Background Papers, World Bank, Washington, DC.
[2] Thenews.com.pk. (2018). Pakistan currently has largest youth population of its history: UNDP report. [online] Available at: https://www.thenews.com.pk/print/311910-pakistan currently-has-largest-youth-population-of-its-history-undp-report [Accessed 22 Nov. 2018].
[3]Kintner-Meyer, M., Schneider, K. and Pratt, R., 2007. Impacts assessment of plug-in hybrid vehicles on electric utilities and regional US power grids, Part 1: Technical analysis. Pacifc Northwest National Laboratory, 1.
[4] Worldometers.info. (2018). Pakistan Population (2018) - Worldometers. [online] Available at: http://www.worldometers.info/world-population/pakistan-population/ [Accessed 18 Nov. 2018].
[5] REPORT, R. (2018). Pakistan's rate of urbanisation highest in South Asia: Symposium told | Business Recorder. [online] Business Recorder. Available at: https://fp.brecorder.com/2017/12/20171230331412/ [Accessed 18 Nov. 2018].
[6] Kiani, K. (2018). New transport policy for sustainable mobility. [online] DAWN.COM. Available at: https://www.dawn.com/news/1414708 [Accessed 18 Nov. 2018].
[7] Nha.gov.pk. (2018). National Highways Authority – Committed to Excellence. [online] Available at: http://nha.gov.pk/en/ [Accessed 6 Nov. 2018].
[8] Anon, (2018). [online] Available at: http://www.pcq.com.pk/Pakistan ChinaTradeCorridor.pdf [Accessed 18 Nov. 2018].
[9] Daily Pakistan Observer -. (2018). Pakistani market has huge automobile potential. [online] Available at: https://pakobserver.net/pakistani-market-huge-automobile-potential/ [Accessed 18 Nov. 2018].
[10] Pama.org.pk. (2018). Production & Sale of Vehicles. [online] Available at: http://www.pama.org.pk/statistical-information/historical-information/annual-sales-production [Accessed 25 Nov. 2018].
[11] Iea.org. (2018). [online] Available at: https://www.iea.org/media/topics/transport/3030CampaignDocumentFinal.pdf [Accessed 18 Nov. 2018].
[12] Boi.gov.pk. (2018). Welcome to the Board of Investment. [online] Available at: http://boi.gov.pk/Sector/SectorDetail.aspx?sid=8 [Accessed 7 Nov. 2018].
[13] Babones, S. (2018). China Could Be The World's First All Electric Vehicle Ecosystem. [online] Forbes. Available at: https://www.forbes.com/sites/salvatorebabones/2018/03/06/china-could-bethe-worlds-frst-all-electric-vehicle-ecosystem/#60afbf3c130f [Accessed 7 Nov. 2018].
[14] Bloomberg.com. (2018). Bloomberg - Are you a robot?. [online] Available at: https://www.bloomberg.com/news/articles/2018-09-06/india-proposes-a-goal-of-15-electric-vehicles-in-fveyears [Accessed 9 Nov. 2018].
[15] Singh, S. (2018). Government plans new policy to promote electric vehicles. [online] The Economic Times. Available at:

https://economictimes.indiatimes.com/industry/auto/auto-news/government-plans-new-policy-to-promote-electric-vehicles/articleshow/65237123.cms
[Accessed at: 7 Nov. 2018].
[16] Unfccc.int. (2018). Introduction of electric vehicles to Sri Lanka by the Lanka Electric Vehicle Association | UNFCCC. [online] Available at: https://unfccc.int/climate-action/momentum-for-change/lighthouse-activities/introduction-of-electric-vehicles-to-sri-lanka-by-the-lanka-electric-vehicle-association [Accessed 9 Nov. 2018].
[17] The Economist. (2018). How China cut its air pollution. [online] Available at: https://www.economist.com/the-economist-explains/2018/01/25/how-china-cut-its-air-pollution [Accessed 18 Nov.2018].
[18] https://www.hindustantimes.com/. (2018). China's air pollution improves, deaths reduced in 74 cities: Report. [online] Available at: https://www.hindustantimes.com/world-news/china-sair-pollution-improves-deaths-reduced-in-74-cities-report/story-OlQbPG7BRLfEPjqBUl9o4L.html [Accessed 18 Nov. 2018].
[19] The Indian Express. (2018). Dust, PM2.5: Delhi air best in three years, says pollution board. [online] Available at: https://indianexpress.com/article/cities/delhi/dust-pm2-5-delhi-air-best-in-threeyears-says-pollution-board-5327937/ [Accessed 18 Nov. 2018].
[20] The Economic Times. (2018). Govt has made 'serious' efforts to curb air pollution: Govt after WHO report. [online] Available at:
https://economictimes.indiatimes.com/news/environment/pollution/govt-has-made-serious-efforts-to-curb-air-pollution-govt-after-who-report/articleshow/64003558.cms/
[Accessed 18 Nov. 2018].
[21] Eos. (2018). Improving Air Quality Could Prevent Thousands of Deaths in India - Eos. [online] Available at: https://eos.org/research-spotlights/improving-air-quality-could-prevent-thousandsof-deaths-in-india/ [Accessed 18 Nov. 2018].
[22] Anon, (2018). [online] Available at: https://www.forbes.com/2009/06/03/cap-and-trade-intelligent-investing-carbon.html#64668a2a1af0 [Accessed 25 Nov. 2018].
[23] Anon, (2018). [online] p.6. Available at:
https://nepra.org.pk/Publications/State%20of%20Industry%20Reports/State%20of%20industry%20report%202017.pdf [Accessed 25 Nov. 2018].
[24] Anon, (2018). [online] p.5. Available at:
https://nepra.org.pk/Publications/State%20of%20Industry%20Reports/State%20of%20industry%20report%202017.pdf [Accessed 25 Nov. 2018].
[25] Anon, (2018). [online] p.10. Available at:
https://nepra.org.pk/Publications/State%20of%20Industry%20Reports/State%20of%20industry%20report%202017.pdf [Accessed 25 Nov. 2018].
[26] Sdpi.org. (2018). [online] Available at: https://www.sdpi.org/publications/fles/A-99.pdf
[Accessed 20 Nov. 2018].
[27] Worldpopulationreview.com. (2018). [online] Available at:
http://worldpopulationreview.com/countries/pakistan-population/ [Accessed 22 Nov. 2018].
[28] South China Morning Post. (2018). 1 million dead and US$38 billion lost: the price of China's air pollution. [online] Available at:
https://www.scmp.com/news/china/science/article/2166542/airpollution-killing-1-million-people-and-costing-chinese [Accessed 23 Nov. 2018].
[29] Xing, Y.F., Xu, Y.H., Shi, M.H. and Lian, Y.X., 2016. The impact of PM2. 5 on the human respiratory system. Journal of thoracic disease, 8(1), p.E69.
[30] AirVisual. (2018). AirVisual Earth - 3D Real-time Air pollution map. [online] Available at:
https://www.airvisual.com/earth [Accessed 24 Nov. 2018].

[31] Department of the Environment and Energy. (2018). Department of the Environment and Energy. [online] Available at: http://www.environment.gov.au/protection/publications/factsheet-nitrogen-dioxide-no2 [Accessed 24 Nov. 2018].
[32] Kampa, M. and Castanas, E., 2008. Human health effects of air pollution. Environmental pollution, 151(2), pp.362-367.
[33] Sbp.org.pk. (2018). [online] Available at: http://www.sbp.org.pk/smefd/circulars/2017/C8-Annex.pdf [Accessed 24 Nov. 2018].
[34] Anon, (2018). [online] Available at: http://www.sbp.org.pk/ecodata/Import_Payments_by_Commodity.pdf [Accessed 25 Nov. 2018].
[35] Unfccc.int. (2018). [online] Available at: https://unfccc.int/fles/adaptation/application/pdf/pakistanneeds.pdf [Accessed 25 Nov. 2018].
[36] Anon, (2018). [online] Available at: https://www.dawn.com/news/1369425 [Accessed 25 Nov. 2018].
[37] Anon, (2018). [online] Available at: https://www.forbes.com/2009/06/03/cap-and-trade-intelligent-investing-carbon.html#e85716e1af05 [Accessed 25 Nov. 2018].
[38] Media.volvocars.com. (2018). Volvo Cars aims for 50 per cent of sales to be electric by 2025. [online] Available at: https://www.media.volvocars.com/global/en-gb/media/pressreleases/227602/volvo-cars-aims-for-50-per-cent-of-sales-to-be-electric-by-2025 [Accessed 25 Nov. 2018]
[39] Pressman, M. and Pressman, M. (2018). Top Electric Car Countries (Charts) | CleanTechnica. [online] CleanTechnica. Available at: https://cleantechnica.com/2017/08/19/top-electric-car-countriescharts/ [Accessed 25 Nov. 2018].
[40] Anon, (2018). [online] Available at: https://timesofndia.indiatimes.com/city/delhi/14-ofworlds-15-most-polluted-cities-in-india/articleshow/63993356.cms [Accessed 25 Nov. 2018].
[41] Technology, I. (2018). 9 English Cities have 'Unsafe' PM10 Levels Envirotech Online. [online]
Envirotech-online.com. Available at: https://www.envirotech-online.com/news/air-monitoring/6/breaking_news/9_english_cities_have_unsafe_pm10_levels/30009 [Accessed 25 Nov. 2018].
[42] Van Donkelaar, A., Martin, R.V., Brauer, M., Kahn, R., Levy, R., Verduzco, C. and Villeneuve, P.J., 2010. Global estimates of ambient fne particulate matter concentrations from satellite-based aerosol optical depth: development and application. Environmental health perspectives, 118(6), p.847.
[43] CARTO. (2018). NO2 hotspots. [online] Available at: https://energydesk.carto.com/builder/4c2ece4f-3367-4432-a418-8ce61ca01801/embed?state=%7B%22map%22%3A%7B%22ne%22%3A%5B24.02639666601734%2C54.20654296875%5D%2C%22sw%22%3A%5B37.52715361723378%2C79.16748046875001%5D%2C%22center%22%3A%5B31.015278981711266%2C66.68701171875001%5D%2C%22zoom%22%3A6%7D%7D [Accessed 25 Nov. 2018].
[44] Anon, (2018). [online] Available at: https://www.reuters.com/article/us-pakistan-airpollution-court/pakistan-moves-to-curb-urban-air-pollution-after-high-court-ruling-idUSKBN1I11B5 [Accessed 25 Nov. 2018].
[45] Anon, (2018). [online] p.25. Available at: http://www.saarcenergy.org/wp-content/uploads/2018/02/ERMT-SAARC-Report-151217.pdf [Accessed 27 Nov. 2018].

[46]Times of Islamabad. (2018). Two Pakistani cities among top 10 worst polluted cities of the World. [online] Available at: https://timesofslamabad.com/29-Sep-2018/two-pakistani-citiesamong-top-10-worst-polluted-cities-of-the-world [Accessed 20 Nov. 2018].
[47]Laghari, A. and Laghari, A. (2018). 8 new automakers got permit to enter into Pakistan auto industry - PakWheels Blog. [online] PakWheels Blog. Available at: https://www.pakwheels.com/blog/8-new-automakers-make-way-pakistan/ [Accessed at: 30 Nov. 2018]



For further details, please contact:

Dr. Naveed Arshad,
LUMS Energy Institute,
Associate Professor, Department of Computer Science,
Syed Babar Ali School of Science and Engineering,
Lahore University of Management Sciences (LUMS),
Opposite Sector U, DHA, Lahore, Pakistan,
Email: naveedarshad@lums.edu.pk
Tel: +92-42-35608190
Cell: +92-300-5551502
http://web.lums.edu.pk/~eig/