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# EFFECTIVENESS OF ELECTRIC VEHICLE POLICIES AND IMPLICATIONS FOR PAKISTAN

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## NOTICE

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Despite many thorough reviews, the authors take full responsibility for all remaining errors or omissions.

## List of Acronyms

BEV	battery electric vehicles
EV	electric vehicle
EVSE	electric vehicle supply equipment
FAME	Faster Adoption and Manufacturing of Electric Vehicles
ICCT	International Council on Clean Transportation
NEV	New Energy Vehicle
NEVP	National Electric Vehicle Policy
NREL	National Renewable Energy Laboratory
PHEV	plug-in hybrid electric vehicles
VMT	vehicle miles traveled
ZEV	zero emission vehicle

# Executive Summary

This report explores evidence from several key countries regarding the impacts to electric vehicle (EV) market penetration from financial incentives, road access policies, EV mandates, fuel taxes, discounted electricity rates, charging infrastructure, and government investment in the domestic automotive industry. It reviews EV policies in countries that have demonstrated success deploying EVs or promoting local EV production, focusing on Norway, China, the United States, India, Korea, Thailand, Indonesia, the Philippines, and Vietnam. The report is targeted toward Pakistan, which is in the process of adopting EV promotion policies, but it is applicable to policymakers throughout the world.

Several lessons are apparent from the EV policies in these focus countries:

- **Financial incentives** are very impactful. Research exploring 2015 EV market shares indicated that subsidies were responsible for approximately 50% of the EV market (Hardman et al. 2018). While battery prices have fallen significantly since 2015 and are projected to continue declining, incentives will likely be important until EVs reach initial price parity with internal combustion engine vehicles (Goldie-Scot 2019). Incentives closer to the point of purchase, such as rebates at the point of sale, are more impactful than income tax credits, which are monetized in the future (Narassimhan and Johnson 2018).
- **Granting exclusive access to EVs**, such as a prohibition of petroleum-fueled two-wheelers in Chinese cities, can make electric versions very popular (Cherry 2010). Lane access policies, such as granting EVs access to high-occupancy vehicle or bus lanes, may be considered as an effective alternative (Narassimhan and Johnson 2018; Hwang 2015).
- **Mandates on automotive manufacturers** to sell EVs can be used to shift the financial burden to subsidize the vehicles, but manufacturers may attempt to renegotiate the mandates if EVs are not profitable (McConnell and Leard 2019). Furthermore, relying on mandates without accompanying government incentives can precipitate declining EV sales, as seen in China (Reuters 2019).
- **Gasoline prices** are significantly correlated with EV adoption (Narassimhan and Johnson 2018). Higher gasoline taxes have been shown to increase both hybrid and EV sales (Belais 2015).
- **Electricity rate discounts** may be less effective (Narassimhan and Johnson 2018). Increasing gasoline taxes may be a more effective policy implementation than providing special EV charging tariffs.
- **Lost revenue from gasoline taxes** may reduce funding for roads. Norway and certain U.S. states are exploring replacement fees based on vehicle miles traveled that could account for other factors such as vehicle weight and efficiency as well as driving location and traffic conditions (Kosche 2020).
- **Charging infrastructure** has an outsized impact on early adopters, so investment in public infrastructure could be valuable at the initial stage of development (Narassimhan and Johnson 2018). Policies requiring the installation of charging equipment in multifamily residential buildings and businesses can address long-term needs in heavy EV adoption scenarios (Vindangos 2020).
- **Policies favoring domestic manufacturers**, such as favorable financing or requiring local manufacturing to qualify for subsidies, have proven effective in the development of EVs that meet the needs of the domestic population (Government of India; Electrive.com 2018).

While certain policies have proven effective in specific countries, it is important to consider exogenous variables, such as median household income, vehicle market, and political regime, that might impact EV policy and success in Pakistan. While this report does not examine those factors in detail, it examines EV policies on a country-by-country basis to provide context that might otherwise be omitted.

# Table of Contents

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
1.1	Country Comparisons .....	1
1.2	Pakistan’s Draft NEVP .....	2
<b>2</b>	<b>EV Markets and Policies.....</b>	<b>4</b>
2.1	Norway.....	5
2.2	China.....	6
2.3	United States .....	9
2.4	India .....	13
2.5	South Korea .....	15
2.6	ASEAN Region.....	16
<b>3</b>	<b>Inferences for Pakistan .....</b>	<b>18</b>
	<b>References.....</b>	<b>24</b>

# List of Figures

Figure 1. Number of vehicles registered in Pakistan (July 2018-March 2019) ..... 2  
Figure 2. Vehicles produced in Pakistan (July 2018-March 2019)..... 2  
Figure 3. EV market share and incentive levels..... 4  
Figure 4. Global electric car sales ..... 5  
Figure 5. Process for an automaker short of China NEV credits ..... 7  
Figure 6. Impacts of direct and indirect policy on EV adoption in China ..... 8

# List of Tables

Table 1. Select Metrics for Countries Analyzed ..... 1  
Table 2. Tax-Adjusted Vehicle Prices in Norway ..... 6  
Table 3. Correlation Between EV Market Variables and Purchases..... 11



# 1 Introduction

Pakistan has drafted a National Electric Vehicle Policy (NEVP) with aggressive goals for electric vehicle (EV) adoption. The draft NEVP includes prospective incentives to help develop the market, and several excellent recommendations are found in Electric Vehicles in Transport (LUMS 2019) as well. However, the Ministry of Industries and Production in Pakistan is investigating the policies that other countries have employed to promote EV adoption for the final NEVP and future revisions.

## 1.1 Country Comparisons

This report explores the primary policy mechanisms for vehicle electrification in several of the top countries for EV deployment as well as mechanisms to drive local manufacturing. It provides examples from Norway, China, the United States, India, Korea, Thailand, Indonesia, the Philippines, and Vietnam. These countries were generally chosen based on EV market penetration, efforts to promote local manufacturing, and the amount of research available on their policies. Although several countries have higher penetration rates than those explored in this report, the authors considered other aspects that make these case studies apt points of comparison, such as India’s vehicle market similarity to Pakistan and the Association of South-East Asian Nations (ASEAN) region promotion of local manufacturing.

The countries from which the examples are drawn provide important context on several levels. The popularity of specific vehicle types, motor vehicle ownership rates, income levels, and other factors will influence the policy decisions that Pakistan makes. Table 1 summarizes population, income per capita, total registered vehicles, and new passenger car EV sales. Data on two-wheeler, bus, and truck EV sales was not generally available for the countries investigated.

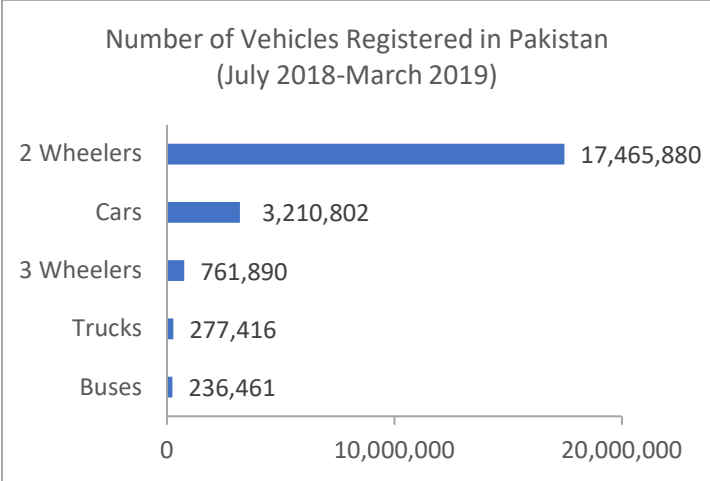
**Table 1. Select Metrics for Countries Analyzed**

Country	Population (UNSD 2020; The World Bank 2020a)	Adjusted net national income per capita (USD) (The World Bank 2020b)	Total Registered Vehicles (WHO 2020)	2019 New Electric Car Sales (IEA 2020)	2019 EV % of All New Car Sales (IEA 2020)
Norway	5,295,619	\$66,019	3,969,612	79,640	55.9%
United States	327,167,434	\$53,490	281,312,446	326,640	2.1%
China	1,392,730,000	\$7,548	294,694,457	1,060,300	4.9%
South Korea	51,606,633	\$25,174	25,680,967	31,860	2.1%
India	1,312,240,000	\$1,740	210,023,289	2,090	0.1%
Thailand	65,700,000	\$5,556	37,338,139	10,320	1.7%
Vietnam	96,208,984	\$2,106	50,666,855	Unknown*	Unknown
Indonesia	266,911,905	\$2,990	128,398,594	Unknown*	Unknown
Philippines	106,598,600	\$3,385	9,251,565	Unknown*	Unknown
Pakistan	212,215,030	\$1,469	21,952,449	Unknown	Unknown

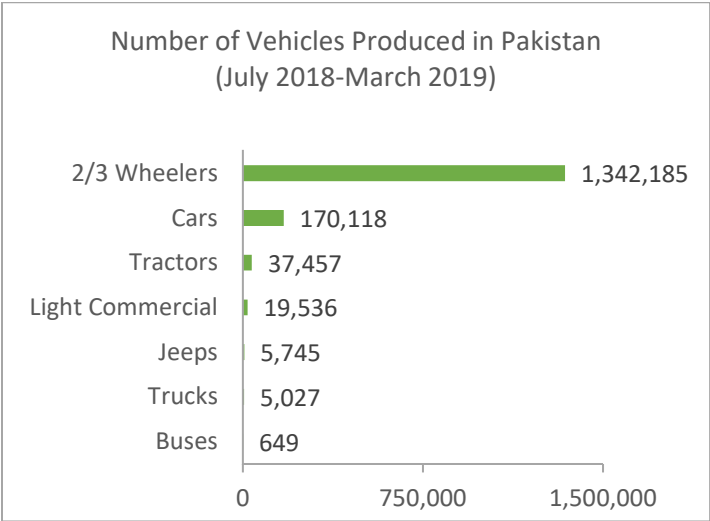
\*There were 1,086 electric cars registered in Vietnam in 2015, approximately 1,000 electric cars registered in Indonesia in 2017, and 64 electric cars registered in the Philippines in 2017 (Biona 2019).



More comprehensive data was reviewed specifically for Pakistan. Figure 1 (Government of Pakistan A) and Figure 2 (Government of Pakistan B) provide context for the Pakistan vehicle market, depicting vehicle registrations and production respectively for different market sectors, which may be useful points of reference for targeting high production vehicle types (such as two- and three-wheelers).



**Figure 1. Number of vehicles registered in Pakistan (July 2018-March 2019)**  
**Data source: Pakistan Economic Survey 2018-2019**



**Figure 2. Vehicles produced in Pakistan (July 2018-March 2019)**  
**Data source: Pakistan Economic Survey 2018-2019**

### 1.2 Pakistan’s Draft NEVP

In 2019, Pakistan proposed aggressive adoption levels for EVs as part of the draft NEVP, including the following:

- 30% of car sales by 2030 and 90% by 2040
- 50% of two- and three-wheeler sales by 2030 and 90% by 2040
- 50% of bus sales by 2030 and 90% by 2040

- 30% of truck sales by 2030 and 90% by 2040 (Uddin 2020; Mustafa 2020).

Pakistan's government agencies are also considering the best ways to foster the domestic EV manufacturing industry. Achieving these goals will require policy intervention in conjunction with improvements to battery technology and reduced EV prices (IEA 2019a). The draft NEVP proposes:

- a reduction in the goods and services tax from 17% for conventional vehicles to 1% for EVs
- lower electricity tariffs for EVs<sup>1</sup>
- an import duty of only 1% for charging equipment
- plans for a direct current fast charging network
- incentives for manufacturers including lower financing rates from the state bank (Uddin 2020).

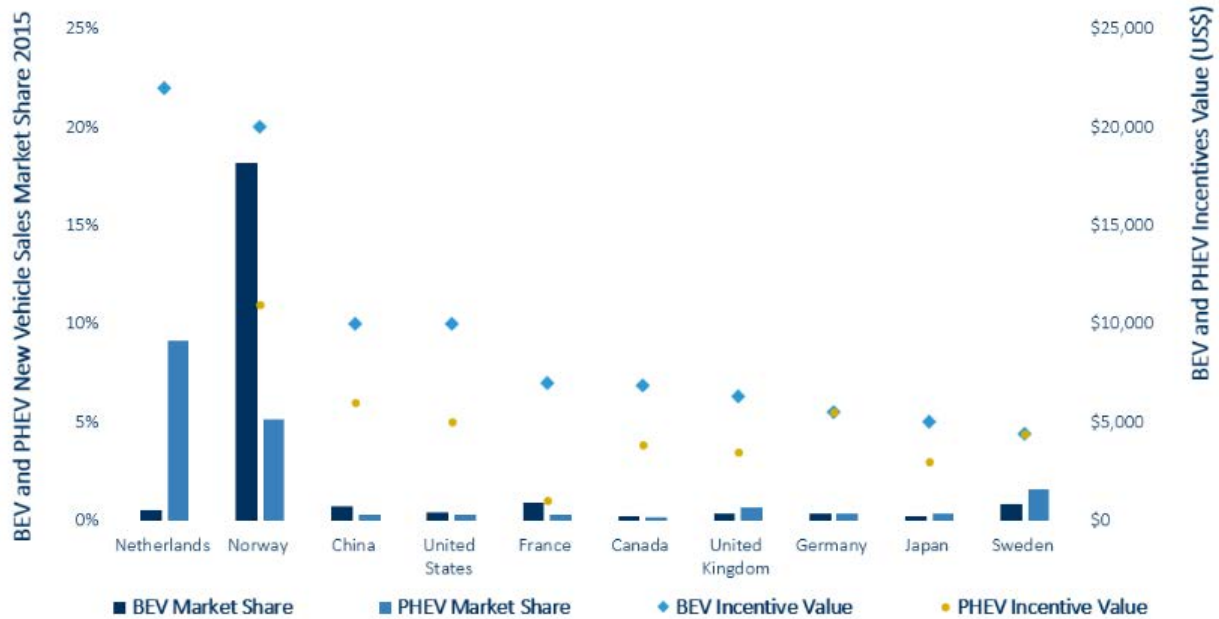
However, Pakistan may need to consider additional incentives and other policy mechanisms to achieve the aggressive goals in the NEVP. This report examines EV support policies around the world to identify examples and lessons that Pakistan can apply in the coming decade.

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<sup>1</sup> In Pakistan, utility rates are already subsidized for residential and commercial customers so further lowering electricity tariffs for EVs might not be feasible.

## 2 EV Markets and Policies

Countries around the world have attempted to influence EV adoption through various policies, including subsidies and tax abatements, mandates on automakers, monetized benefits for EV drivers like exemption from toll road or parking fees, deployment of charging stations, and road access policies that make restricted areas or lanes available to EVs. A report from University of California-Davis compares the incentive levels in different countries to adoption rates (Hardman et al. 2018). The results indicate that significant EV incentives were necessary to capture a significant market share in 2015 (Figure 3). The report states that incentives may have accounted for approximately 50% of all EV sales.



**Figure 3. EV market share and incentive levels**

**Source: Hardman et al.**

Since 2015, EV adoption rates have generally increased through the world (IEA 2020), while battery costs have fallen (Goldie-Scot 2019). Of the countries depicted in Figure 4, nearly all showed an increase in EV market share from 2015 to 2018 with the exception of plug-in hybrid electric vehicles (PHEVs) in the Netherlands (*Auto & Fiscus* 2016).

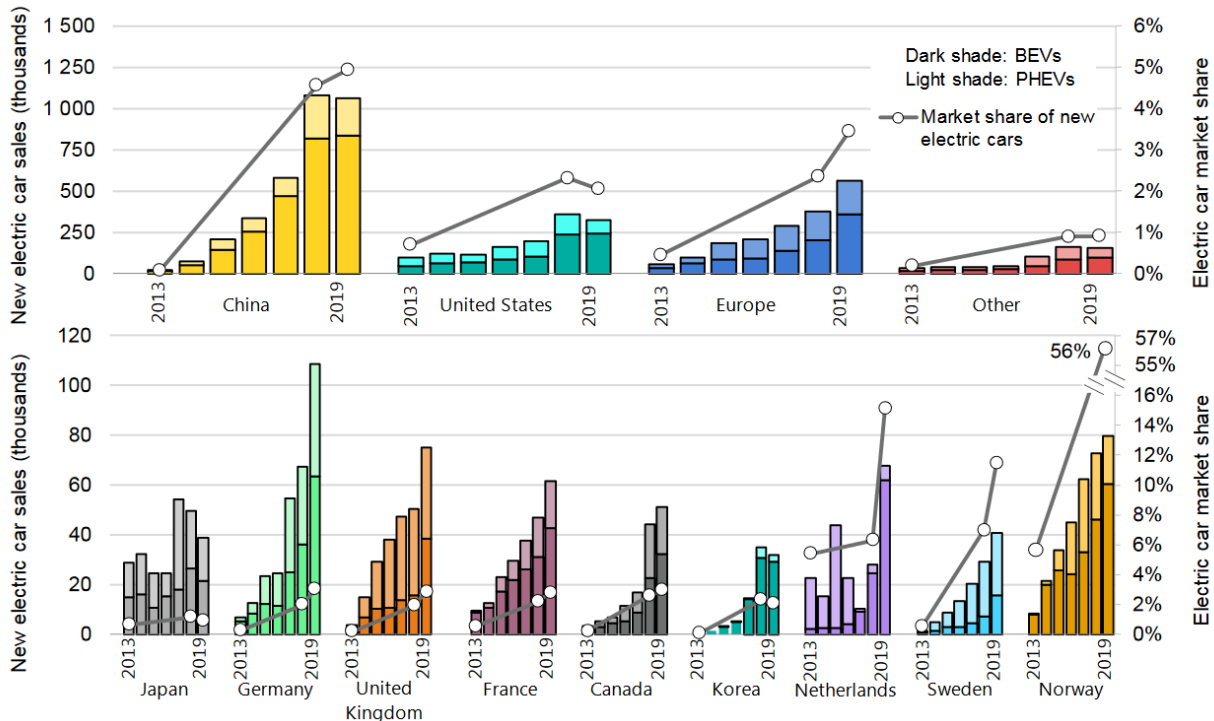


Figure 4. Global electric car sales

Source: IEA 2020

## 2.1 Norway

Norway has the greatest penetration of EVs in the world on a percentage basis (56% of 2019 car sales), and the government provides a litany of incentives. Norway has eliminated import taxes on EVs; exempted the 25% value-added tax and road tax; limited ferry, municipal parking, and toll road fares to 50% of what petroleum vehicles pay; and reduced company car taxation to 40%. Various jurisdictions provide access to bus lanes and EV-specific parking lots. Through these incentives, the initial cost of EVs are often lower than comparable gasoline vehicles (*Norsk elbilforening*). Even with lower initial costs and additional benefits such as reduced parking and toll road fares in addition to lower fuel prices, EVs roughly split sales with gasoline vehicles in 2019.

Research comparing the EV incentive policies in Norway, France, Germany, the Netherlands, and Korea stated that a key differentiator in Norway was private vehicle access to bus lanes and exclusive EV parking lots (Hwang 2015); however, a report comparing Norwegian municipalities and counties indicated that toll exemptions and the right to use bus-designated lanes were not good predictors of EV sales, while access to EV charging infrastructure, proximity to major cities, and regional incomes were the best predictors of EV sales (Mersky et al. 2016). The policies in Norway evolved over time; despite being introduced in 1990, these efforts did not start to move the needle until 2010 when major automakers began selling mass-market EVs with lithium-ion batteries (Figenbaum 2017).

Another report examining the effectiveness of different policies in the European Union on adoption of EVs in the largest European cities placed Oslo, Norway, second in terms of policies promoting EVs (including incentives, charging benefits, and general strategies), offering 16 out of 20 possible promotional efforts (Wappelhorst 2020); London offered the most with 17 promotional efforts, but 2019 EV adoption rates in the United Kingdom were only 2.8%, below the 3.5% market share in Europe as a whole (IEA 2020).

Two factors stand out when comparing Norway to the United Kingdom. First, the incentive levels in Norway are much higher than in the United Kingdom. By exempting EVs from their emission taxes, weight tax, and value added tax, they reduce the total initial price of the EV in the example below by 11,781 euros (\$12,875) (Table 1). This makes certain EVs cheaper than gasoline vehicles, and Norway offers usage incentives on top of the financial incentives. In contrast, the United Kingdom was offering a grant of £4,500 (\$5,607) for battery electric vehicles (BEVs) and £2,500 for PHEVs until 2017. The country reduced BEV incentives to £3,500 and eliminated PHEV incentives in 2017 (Jolly 2019), and now the BEV incentives are limited to £3,000 (Gov.uk). Both incentives would be rolled into the initial price of the vehicle at the dealership. The second potentially significant factor is that the average income in Norway is the world’s highest at \$66,019, while average income in the United Kingdom is \$35,837 (The World Bank 2020b).

**Table 2. Tax-Adjusted Vehicle Prices in Norway (Data source: Norsk elbilforening)**

Vehicle	Volkswagen Golf	Volkswagen e-Golf
Price Before Taxes	€ 22,046	€ 33,037
CO <sub>2</sub> Tax	€ 4,348	€ -
NO <sub>x</sub> Tax	€ 206	€ -
Weight Tax	€ 1,715	€ -
Scrapping Fee	€ 249	€ 249
25% Value Added Tax	€ 5,512	€ -
Price After Taxes	€ 34,076	€ 33,286

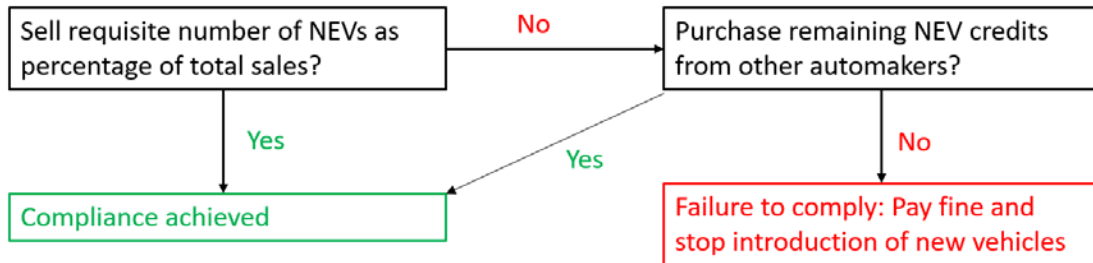
With the increasing penetration of EVs coupled with expensive toll roads, Norway is exploring a system for funding road construction and maintenance based on vehicle miles traveled (VMT) that may account for other factors, such as vehicle emissions, axial load, population density, and time of day (Kosche 2020). The program could potentially replace road tolls, fuel taxes, and flat vehicle registration fees as a complete road funding system. Norway is piloting the project by collecting data on vehicle characteristics, VMT, and location. The pilot uses a dynamic pricing system to encourage drivers to avoid congested roads and hours, called “dynamic pricing with green geofencing.” Data will be collected on the use case throughout 2020 before the government of Norway decides whether to adopt it (Ibid).

**Implications for Pakistan:** Norway has a much greater EV penetration than any other country. Their market penetration rates are approximately 10 times that of China and 20 times that of the United States, while their incentive levels are nearly double those of the two other countries. These incentive levels bring EVs to cost parity with gasoline vehicles, which may indicate a tipping point where EVs grow from a small market segment to nearly half of all car sales. However, there are several convoluting factors such as the high-income levels in Norway and a variety of use-based incentives, such as access to bus lanes. Pakistan might learn from Norway in these examples if it does not have the resources to offer significant purchase incentives or rebates. In addition to bus lane and parking lot accessibility, Norway imposes high taxes on gasoline vehicles and simply exempts EVs from those taxes, mitigating the loss of revenue through other means.

## 2.2 China

China has the largest overall market for EVs, exceeding 1,000,000 EVs sold and 4.9% of the car market share in 2019 (IEA 2020). China is also the largest market for electric two-wheelers in the world, totaling 20 million sold and 100 million on the road as of 2010, which constituted approximately 90% of their motorized two-wheeler market (Cherry 2010).

China’s primary policy for larger vehicles is the New Energy Vehicle (NEV) policy, which provides subsidies to consumers for vehicles and requires that automakers obtain 12% NEV credits in 2020 either by selling qualifying vehicles or purchasing credits from their competitors. Each individual EV sold may qualify for as many as six NEV sales credits. The International Council on Clean Transportation (ICCT) estimates that the average EV would earn about three credits, setting the actual passenger car sales target at 4% for 2020 (ICCT 2018). Figure 5 illustrates the pathways for compliance and consequences for failure to meet the NEV goals.



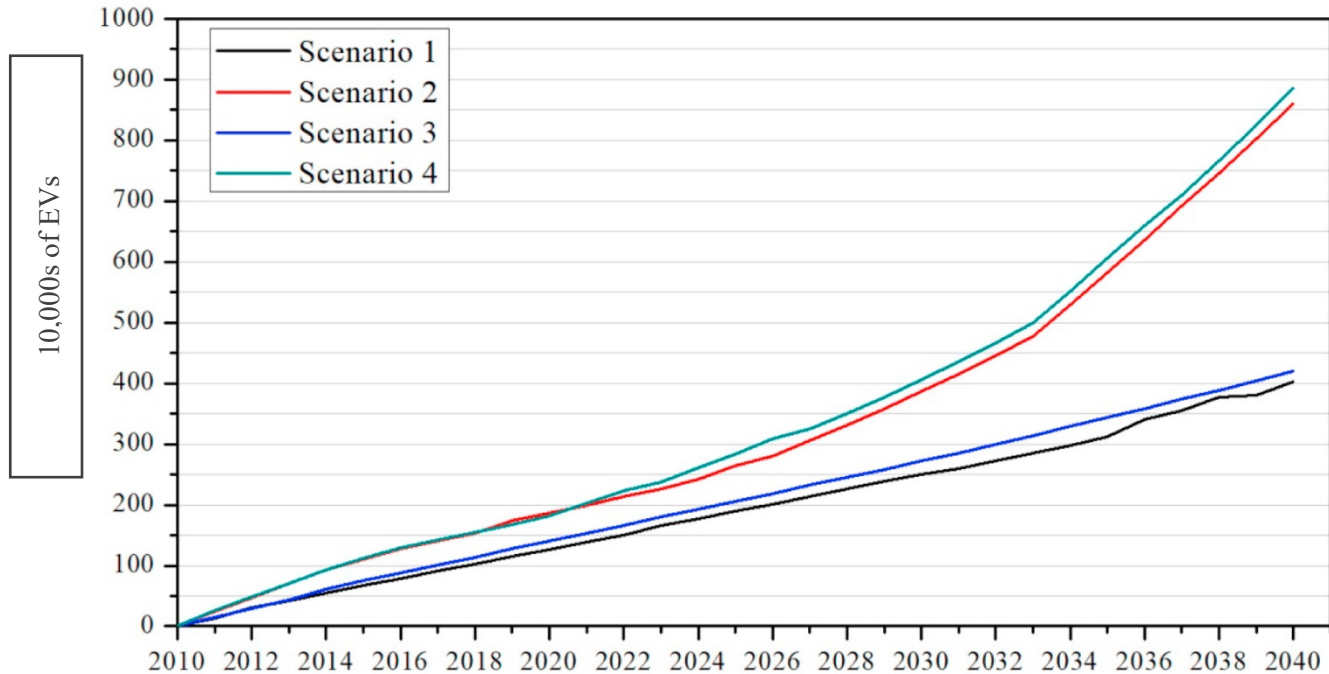
**Figure 5. Process for an automaker short of China NEV credits**

China’s NEV policy was also providing incentives by exempting EVs from the 17% value-added sales taxes and offering rebates estimated at \$7,000 for a BEV and \$4,000 for a PHEV in 2017-18 (which are matched at up to 50% in certain cities) (Hughes-Cromwick). Several major cities, driven by air quality and congestion concerns, have exempted EVs from license plate fees and license plate lottery systems that can be worth as much as \$16,000 (Hughes-Cromwick).

China cut EV incentives in July 2019, which immediately impacted EV sales; sales of hybrid and EVs sank 34% in September 2019 and 46% in October (Shepherd 2019; Reuters 2019). The value reduction of the incentives varies by battery capacity, electric range, efficiency, weight, and whether the purchaser is private or commercial. ICCT uses the sale of a Roewe eRX5, a typical SUV, to a private purchaser as an example to illustrate a 70% reduction in the central government subsidy (ICCT 2019). The impact to sales illustrates the effectiveness of the incentives themselves as well as the problems with rolling back subsidies. In addition, China restricted the subsidy scheme by applying stricter constraints, such as requiring an electric range for a BEV of 250 km instead of 150 km (ICCT 2019). These changes were designed to improve the quality of EVs in China.

**Sri Lanka**, in contrast, provides incentives for EVs with small motors (less than 70 kW) and actually imposes additional taxes on EVs with motors greater than 150 kW). The Kia Lanka Chairman has reported that this makes importing most vehicles “not competitive or feasible” (Rodrigo 2019).

A report analyzing the impact of direct and indirect policy in China found that direct policy intervention (subsidies and mandates) had a significant effect on EV adoption, whereas the impact of indirect policy intervention (overarching energy and environmental policy such as a carbon credit system) had minimal impact on EV adoption, partly based on the low price of carbon at the time (Liu 2018). In Figure 6, from the report, Scenario 1 represents no policy intervention, Scenario 2 represents direct policy only, Scenario 3 captures the impacts of indirect policy (particularly the ~\$3.00 USD/ton carbon tax), and Scenario 4 combines direct and indirect policy. The axis represents tens of thousands of total electric vehicles.



**Figure 6. Impacts of direct and indirect policy on EV adoption in China**

**Liu and Xiao 2018**

EV sales sank for a period in 2019 despite the NEV mandate remaining intact, suggesting that purchase incentives may be a larger factor for EV penetration than government targets in the short term. The NEV mandate is a modified version of California’s zero emission vehicle (ZEV) mandate, which was unsuccessful in its early years. Although California’s ZEV mandate was introduced in 1990 and a goal of EVs as 10% new vehicle sales by 2001, EVs did not enter the mainstream automotive market in the United States until 2010 (McConnell and Leard 2019). The NEV mandate in China did not take effect until April 2018; therefore it did not attempt to play the same market-forcing role that the California ZEV mandate did (IEA 2019b).

In contrast, China was attempting to rely more heavily on the quota program while winding down incentives in order to shift the responsibility of subsidizing EVs onto automakers (Berman 2019); however, because the EV market has trended downward since reducing incentives in 2019 (Berman 2020), the central government is pressuring municipalities to increase subsidies and are considering following suit federally. China has designated EVs as one of ten high-tech industries in its “Made in China 2025” industrial policy 10-year plan (McBride and Chatzky 2019). This plan is designed to shift China from being a low-end manufacturer to a high-end producer of goods.

Several Chinese cities have implemented restrictions regarding the acquisition and operation of motor vehicles. An analysis of policy incentive effectiveness in 2016 found that Chinese consumers were more motivated by rescinding the restrictions to purchase (license plate control policy) and drive EVs than any other policy; they were valued by the customers at \$7,343 and \$4,900, respectively (Wang, Tang, and Pan 2017). Because purchasing internal combustion engine vehicles in Beijing and Shanghai was restricted, being able to purchase a vehicle was valued most highly, followed by driving EVs including access to bus lanes. Those attributes were followed in value by longer driving range (provided the longer-range vehicles were not too expensive), free public charging, and purchase tax exemption.



The rise of two-wheelers in China is mostly attributed to the central government designation of electric two-wheelers as bicycles, provided they are limited to 40 kg and a maximum speed of 20 km/hour, paired with many cities restricting gasoline motorcycles in their urban cores (Cherry 2010). As “bicycles,” these vehicles could also travel in bicycle lanes, and they did not require driver’s licenses or registration. Furthermore, enforcement of the weight and speed limits was lax, and vendors were offering faster bicycles with speedometers capped at 20 km/hour (Cherry 2010).

Because the nominal speed of electric two-wheelers is below the 100 km/hour minimum requirement to qualify for EV incentives, they are not subsidized in China (ICCT 2018). Thus, it appears that an outright ban on gasoline options is extremely effective at growing the market for the electric alternative while a mandate directed at automakers for EVs may be less so.

China is heavily supporting bus and truck electrification as well. In Shenzhen, where all 16,000 buses have been 100% electric since 2018, local and central governments have provided large subsidies (\$72,000 per year per vehicle, with the Shenzhen municipality providing 80% of that subsidy, and the central government covering the rest) (Ren 2018). Shenzhen, located adjacent to mainland Hong Kong, is home to BYD auto manufacturer, and 80% of the electric bus fleet were BYD, an example of support for local manufacturing (Lu, Xue, and Zhou 2018).

**Implications for Pakistan:** China is addressing the electrification of four-wheel passenger vehicles and electric buses in a very different manner than two-wheelers. China introduced significant incentives for four-wheelers along with a mandate on automotive manufacturers to sell the vehicles. This approach has been successful, although it appears that the purchase incentives may be the more impactful factor, at least in the short term. Pakistan should take note of the immediate drop in sales when EV incentives were cut in 2019 in China. Pakistan’s NEVP implementation should consider more gradual changes to any incentive level modifications.

China’s electric bus market may be driven even more heavily by purchase incentives, as illustrated in Shenzhen. It is important to tailor incentives to promote desirable vehicles for long-term market success such as a longer-range requirement as opposed to excluding certain vehicles as was done in Sri Lanka.

By banning petroleum two-wheelers and giving small electric two-wheelers access to bicycle lanes in crowded cities, China created the largest market in the world for the latter. This suggests that an outright ban on gasoline alternatives in key locations can catalyze a major market shift, while evidence from China and the United States indicates that mandates on automotive manufacturers might not be sufficient on their own. Since Pakistan has a similar exemption for registration of e-bikes of 35 cc or less, it could use bicycle lanes as an access incentive which may spur sales in congested areas. However, acknowledging that infrastructure constraints and low enforcement capacity create a barrier to zonal restrictions or access incentives, Pakistan may consider focusing on reducing capital costs for new e-bikes as well as lower costs for conversion of existing ICE bikes. Two-wheelers are the entry point for vehicle ownership and dominated by low-income buyers who are extremely sensitive to both initial and ongoing vehicle costs.

## 2.3 United States

The United States has a national policy in place that provides a federal income tax credit up to \$7,500 for EVs with a phase-out process once an automaker sells 200,000 EVs (Congressional Research Service 2019). The tax credits are targeted toward cars with stipulations that the EV batteries have at least five kWh of capacity and a gross vehicle weight rating of up to 14,000 lbs (6,350 kg) (Congressional Research

Service 2019). Several states offer additional tax credits, rebates, or sales tax waivers, and many have invested heavily in developing charging infrastructure to spur market adoption (DOE).

The federal government also requires that automotive manufacturers achieve improvements in fuel economy as part of the Corporate Average Fuel Economy program, with a 1.5%-5% increase in stringency per year (NHTSA 2020). EVs are used by many manufacturers to achieve compliance due to their fuel economy ratings exceeding 100 miles per gasoline gallon equivalent (>42 km/liter).

Eleven U.S. states mandate that automakers sell a growing percentage of ZEVs as a percentage of total sales; in the alternative, manufacturers can purchase credits from other automakers or pay a fine. The ZEV mandate was originally introduced in California in 1990, targeting 2% ZEV sales for large volume manufacturers in 1998 and ramping up to 10% in 2003 (Kemp 2005); however, the mandate was relaxed multiple times through lobbying and litigative efforts by manufacturers that invested more heavily in political influence than research and development as assessed by patent filings obtained through the European Patent Office's Global Patent Index. From 1990 to 2013, General Motors, Nissan, and Toyota moved from defensive political strategies to oppose or slow the regulations to proactive political strategies to shape or support them and simultaneously increased patent filings for ZEV technology (Esseling, Farla, and Hekkert 2015).

ICCT has found that regions with ZEV mandates (U.S. states, China, and the European Union) have more ZEV models available and higher ZEV sales than other regions (Tokadiya and Yang 2019), although the correlation is clouded by the presence of other promotional policies (Lutsey et al. 2015). California (the original ZEV state) led the country in terms of EV market share as a percentage of the state's total light vehicle sales in 2018, and Oregon (another ZEV state) placed third. In addition, ZEV mandates have served to foster EV innovation activity and industry investment that are important to local EV production (Hardman et al. 2018). However, states without a ZEV mandate on auto manufacturers, such as Washington state, the District of Columbia, Colorado (not yet a ZEV state for the 2018 data presented), and Hawaii claimed four of the top six EV market shares at the time (EV Adoption 2018). That was accomplished with combinations of tax breaks, rebates, and various charging infrastructure programs.

A study of policy efficacy in U.S. states showed that rebates at the point of sale were more impactful than sales tax waivers, which in turn were more impactful than income tax credits, typically received much later (Narassimhan and Johnson 2018). Table 3 summarizes the impacts of policy measures and other metrics on the sales of all plug-in electric vehicles, as well as impacts to PHEVs and BEVs independently as shown by the main model in the cited report. The table covers nonmonetary incentives such as charging stations and high-occupancy vehicle lane exemption, as well as factors such as environmental awareness and household income that may impact EV adoption.

**Table 3. Correlation Between EV Market Variables and Purchases (Source: Narasimhan and Johnson 2018)**

State Level Correlation of EV Market Variables on Per Capita EV Purchases	Incremental Change	EV	PHEV	BEV
Explanatory Variables	Increase/Decrease by	Increases purchases by	Increases purchases by	Increases purchases by
Charging stations per hundred thousand population	1	3.1%	2.6%	7.2%
Tax credit (in dollars)	\$1,000	2.3%	Not significant	5.3%
Rebate (in dollars)	\$1,000	4.8%	Not significant	7.7%
Sales tax waiver (in dollars)	\$1,000	3.6%	Not significant overall; 1.6% for Volt	5.9%
High-Occupancy Vehicle Lane Exemption (Yes or No)	if Yes	8.3%	8.1%	14.5%
Home Electric Vehicle Supply Equipment (EVSE) credit	If Yes	Not significant	Not significant overall; 26.0% for Volt	Not significant
Home charging discount	If Yes	Not significant	Not significant	Not significant
Gasoline price	1%	0.6%	0.5%	0.8%
Environmental awareness (based on that state's League of Conservation Voters legislators scores)	1-point increase	Not significant	Not significant overall; 0.1% for Volt and 0.2% for Prius	Not significant overall; 0.1% for Tesla Model S
Median Household Income	1%	0.3% [sic]	0.4%	0.5%
Unemployment rate	1%	Not significant	Not significant	Not significant
Vehicle miles traveled per capita	1%	Not significant	Not significant	Not significant

Table 2 shows that charging infrastructure is correlated with EV purchases, and the study correlates charging stations, also known as EVSE, installation with EV purchases in the following quarter to support this assessment, and finds that the correlation is especially strong for early adopters. The United States offers a 30% federal income tax credit capped at \$30,000 for the installation of EVSE to private businesses, as well as a federal income tax credit up to \$1,000 for the residential installation of EVSE (AFDC 2020). An overview of existing research shows that public charging needs vary by country based on the degree of private charging available at home and at the workplace (Funke et al. 2019). There is reason to believe this is the case with different types of vehicles as well. For example, buses require dedicated private charging, but cars and trucks need access to public charging for EV market penetration to accelerate. The 2021 International Energy Conservation Code includes requirements to install sufficient electrical capacity for one EVSE in new homes and for 20% of all parking spaces at businesses and multi-family residential buildings (Vindangos 2020).

As noted in Table 2, a 1% increase in gasoline tax can increase EV acquisitions by 0.6%. Furthermore, unpublished research by Jonathan Belais at the Colorado Office of Economic Development and International Trade indicated that the existing gas tax of 22 cents per gallon in the state of Colorado accounted for 2.65% of all hybrid electric vehicle penetration and likely a similar percentage of EVs. (Belais 2015). The research suggests that increases to the gasoline tax would increase the penetration of hybrid vehicles and EVs. Pakistan gasoline prices from March 9, 2020 to June 15, 2020 averaged 91 PKR/liter (2.11 USD/gallon), less than half of the world average price of 188.09 PKR/liter (GlobalPetrolPrice.com 2020).

Several U.S. states have instituted annual registration taxes to counteract the lost revenue from gasoline taxes. EV registration fees range from \$50 to \$200/year (Market Watch 2019). While these programs may eventually replace the lost revenue from gas taxes, they serve as a disincentive to EV adoption. Oregon began piloting a road-usage charge program in 2015 as a long-term solution to lost gas tax revenue. Drivers of EVs or conventional vehicles can participate, and they pay 1.7 cents per vehicle mile traveled (VMT) in lieu of a flat annual registration fee for EVs or a refund of 34 cents per gallon for gasoline vehicles (Association of Oregon Counties 2020; St. John 2019). California is exploring a similar program that may include using telematics to capture miles driven (California State Transportation Agency 2017). These programs are similar to tolls charged on specific roads except that they can be applied statewide. A VMT-based approach is technology neutral and does not discourage EV adoption; instead, it disincentivizes driving more broadly.

Utilities in the United States have attempted to incentivize EV adoption by offering discounted electricity rates for home charging. Published research on this impact is less extensive than many other factors, but the indication is that these discounts were not a significant factor driving EV adoption in the United States (Narassimhan and Johnson 2018). While this could be due to consumer propensity to discount future savings, that does not comport with the impacts of a gasoline tax. Discounted electricity rates might not have a significant impact because EV-specific electricity rates are more obscure to the public than gasoline prices. It may also be that public perception is such that electricity rates are not high enough to warrant the behavior change were they to be lowered

EV sales in the United States grew significantly from 199,826 vehicles in 2017 to 361,307 in 2018, when Tesla ramped up production of the Model 3 to meet latent demand (Loveday 2018). EV market penetration then flattened in 2019 as incentives for General Motors and Tesla vehicles began to phase out (Argonne National Laboratory; Edmunds 2019). Tesla also received a loan in 2010 from the U.S. government Advanced Technology Vehicle Manufacturing program that helped them scale their business, which they paid off three years later (Tesla 2013).

**Implications for Pakistan:** Not all financial incentives are equally impactful on EV market share. Rebates at the point of sale are more effective than sales tax waivers, which in turn are more effective than income tax credits. This may be a result of hyperbolic discounting among consumers as well as the simplicity of marketing rebates. High-occupancy vehicle exemptions are significant as well, furthering the evidence that access policies and usage incentives can drive EV sales.

The installation of charging stations has a significant impact on EV market penetration rates and is especially effective with early adopters. The availability of private charging may vary for different types of vehicles in Pakistan. Two-wheelers, as the most common vehicle type in Pakistan, will require access to charging at home. The power requirements for two-wheelers like the Jolta e-125 sold in Pakistan with a 1.8 kWh battery pack could be serviced overnight by 1-A chargers on 230-V service; however, to transition a majority of Pakistan's 12 million two-wheelers to electric will require a policy to make charging available in multi-family units such as apartment buildings and a share of workplaces as well. The 2021 International Energy Conservation Code provides guidance for achieving that goal.

One of the more surprising conclusions from Table 2 is that discounted electricity tariffs for EV charging are not significantly correlated with EV adoption, but gasoline prices are. Increasing gasoline taxes appears to be a viable method to incentivize EVs and potentially counteract the lost revenue from widespread EV adoption. Oregon and other states are pursuing alternatives to gas taxes to fund roads, such as road usage based fees that are assessed based on miles driven. Oregon refunds gasoline taxes and EV registration fees in exchange for participating in the VMT tax program.

## 2.4 India

India has prioritized EV adoption through the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, originally launched in 2015 and replaced by FAME-II in 2019. The program is designed to catalyze EV market adoption and local manufacturing.

Localization—the percentage of vehicle parts sourced from within India—has been a major facet of the FAME program. Among other elements, the FAME-I program required at least 15% localization for buses to qualify for incentives up to 8.5 million Indian Rupees (\$112,179) per bus and 35% localization to qualify for 10 million Indian Rupees (\$131,976) (UITP India). The FAME incentive committee plans to increase the localization percentage to qualify for any grants under FAME-II from 50% to 70% over time (Government of India). In the bus market, this has resulted in local companies such as Tata and Ashok Leyland launching products and foreign companies partnering with Indian companies, such as BYD-Olectra which has already opened an electric bus plant in India and plans to build a second one (Electrived.com 2019).

The FAME-I program initially provided incentives for hybrid vehicles, PHEVs, and BEVs with different incentive caps based on vehicle segment (scooters, motorcycles, three-wheelers, four-wheelers less than four meters long, four-wheelers greater than four-meters long, light commercial vehicles, and buses) at two tiers based on fuel consumption (10%-30% and above 30%). The program also included funding to test vehicles and infrastructure, deploy charging infrastructure, and fund pilot projects (Government of India 2015). The incentives were initially restricted to India's "Smart Cities" and certain other large cities (generally cities with greater than 1 million people); however, two- and three-wheeler incentives were made available throughout India six months after the launch of the program (*Gazette of India* 2015).

FAME-II focuses on BEVs primarily and extends to PHEVs and hybrid vehicles<sup>2</sup> in the four-wheeler market. For BEV, it covers, buses, four-wheelers, three-wheelers, and two-wheelers. The FAME-II incentive scheme is displayed in Table 4. The incentives are captured by manufacturers, but the dollar value must be transferred to consumers at the time of sale (Government of India 2019).

**Table 4. Incentives by Vehicle Type Under FAME-II (Source: Jaiswal 2018)**

Category of vehicle	Type of vehicle	Demand incentive (INR/kWh battery capacity)	Cap on demand incentive (as % cost of vehicle)	Maximum number of vehicles to be supported	Approximate battery size (kWh)	Maximum ex-factory price to avail incentive (INR)
Buses	BEV	20,000	40%	7,090	250	20,000,000
Four Wheelers	BEV, PHEV, full hybrid	10,000	20%	55,000	EV: 15 Hybrid: 1.3	1,500,000
Three-Wheelers	BEV	10,000	20%	500,000	5	500,000
Two-Wheelers	BEV	10,000	20%	1,000,000	2	150,000

The EV market share of car sales remains low in India at 0.1% in 2019 (Global EV Outlook 2020), but 152,000 electric two-wheelers were sold in the 2019-2020 fiscal year along with 600 electric buses (Frangoul 2020). According to the Climate Group: “During 2017-18, 47,912 two-wheelers, 2,202 three-wheelers, 185 four-wheelers and 10 light commercial vehicles were supported under the FAME scheme” (Shah 2019). Although the two-wheeler sales are most impressive and appear to be growing rapidly, in 2019, 21.19 million two-wheelers were sold in India (Research and Markets 2020), indicating that electric two-wheelers have yet to take 1% of the market share.

The Indian government has discussed issuing a mandate for only electric three-wheelers as of April 2023 and all new electric two-wheelers with engine capacity up to 150 cc as of April 2025 (Dash and Sidhartha 2019). Two-wheelers account for over 80% of the vehicle market in India, so the impact of this proposal would be sizeable (Statistica). An inter-ministerial steering committee has proposed the concept, but it had not been mandated as of March 2020.

The ICCT developed an *EV Guidebook for Indian States* that includes policy and other recommendations for India that may be applicable to Pakistan as well (Menon, Yang, and Bandivadekar 2019). Among other recommendations, it discusses the need to subsidize research and development for the domestic automotive industry to increase EV production capacity as well as the importance of raising public awareness.

<sup>2</sup> A traditional hybrid vehicle fuels exclusively with gasoline but recaptures energy from braking in a small traction battery to improve efficiency. A PHEV has a gasoline tank and a larger traction battery that can charge from external electricity sources. Most PHEV cars have an electric driving range of 30-50 km supplemented by a much longer gasoline driving range. A BEV only has a traction battery and typically a much longer electric driving range than a PHEV. For example, the 2020 Chevrolet Bolt EPA-rated range is 417 km.

**Implications for Pakistan:** India's vehicle market is similar to that of Pakistan, including the high percentage of two-wheeler penetration. The Indian government's goals also mirror Pakistan's. Both countries are trying to develop local industry as well as transition to electrified transportation. The localization levels for buses that India initially set at two grant levels (15% and 35%) followed by increasingly high localization requirements for similar grants (up to 50% then 70%) may provide a good example for Pakistan to consider. India's requirements resulted in local manufacturers (e.g., Tata and Mahindra) developing electric alternatives, while others partnered with foreign companies with EV expertise (e.g., BYD) that will manufacture vehicles locally. Pakistan should review the localization rates in India for different market segments and tailor national requirements to their national market. However, it should be noted that for two-wheelers, even with an aggressive program, the penetration is growing slowly due to the large legacy fleet.

## 2.5 South Korea

The Republic of Korea announced a goal in 2019 for 33% of new vehicle sales to be EVs by 2030 (Electrived.com 2019). Korea is driving EV adoption primarily through purchase subsidies, accounting for 8 million won (~\$6,600 USD) for BEVs and waiver of the 5% excise tax (Electrived.com 2019). In addition, Korea is attempting to claim international market share by providing liquidity support and loan guarantees to domestic manufacturers such as Hyundai and Kia. The country is aiming to grow EV exports from 36,000 in 2018 to 250,000 vehicles by 2022 (Electrived.com 2018).

The initial years of Korea's EV policy framework were much less successful than their lofty goals. Korea had set a goal of 1 million EVs on the road by 2020 with interim deployment targets, including 35,100 vehicles in 2014; however, only 3,044 EVs were on the road in 2014. Some analysis suggested that Korea should focus more heavily on usage incentives (Hwang 2015). Since then, Korea's growth in EV sales has been impressive, and the country exceeded 2% of car sales in 2018, similar to average market penetration in Europe in 2018 (IEA 2019a), although Korean EV sales declined slightly in 2019 (IEA 2020). The increased market penetration appears to be tied to the development of domestic EVs, starting with the Hyundai Ioniq, expanding to the Kia Niro, and now including the Hyundai Kona (Kane 2017; Kane 2019). Korean EV sales grew by 37% from January-May 2019 over the same period in 2018, while their EV exports surged in late 2018 as the Hyundai Kona Electric hit international markets (Argus Media 2019; Kane 2020). Statistical analysis of EV sales in Korea finds a correlation between longer vehicle range and increased EV market penetration, while it finds that fuel economy improvements from one EV to another do not increase consumer purchases (Kim and Heo 2019).

**Implications for Pakistan:** Korea's introduction of incentives was not immediately effective at creating a market for EVs. EVs did not take off in the country until domestic manufacturers began introducing electric options. The global popularity of these domestic options helped the momentum. This is similar to the United States, where the introduction of the Tesla Model 3 corresponded to a significant jump in EV sales. This report does not use a quantitative approach to control for technology improvement and the reduction in battery costs, but the introduction of domestically produced new models appears to be tied to EVs gaining popularity in Korea with the Ioniq and the Niro and in the United States with the Model 3, and China with several models from BAIC, BYD, and others. This suggests that fostering the domestic automotive industry can play an important role in popularizing EVs locally.



## **2.6 ASEAN Region**

Many ASEAN countries are promoting EVs with a focus on manufacturing them domestically. This includes both foreign automotive manufacturers building factories and domestic automakers developing EV models. The objective is to develop domestic industry activity, both for vehicles and for parts, instead of relying on imports to shift to cleaner and more efficient transportation. Below are some examples of measures countries have taken, specific to their auto industries.

### **2.6.1 Thailand**

Thailand has focused on automakers and foreign investors for production of EVs, rather than incentives for potential buyers on the demand side for EVs. These policies include corporate income tax exemption for up to eight years, permission to take out or remit money in foreign currency, reduced import tariffs on machinery, and raw material privileges (Rastogi 2018; Amir 2020). Thailand announced a roadmap to promote production of 250,000 electric cars, 3,000 electric buses, and 53,000 electric motorcycles by 2025 (Amir 2020). The EV plan further aims for EV production to total 30% of annual car production by 2030 (Ibid). Incentives for automakers and component suppliers have drawn interest from Honda, Mazda, Nissan, Toyota, Audi, BMW, Mercedes-Benz, and Mitsubishi.

The Thai government has a commitment to produce at least 1.2 million EVs by 2036 and EVs at 40% market share out of all automobiles by 2040. Thailand has already achieved 1.7% EV penetration in the domestic car market, although electric car sales in 2019 only totaled 10,320 (IEA 2020).

### **2.6.2 Indonesia**

Indonesia provides incentives for EVs registered by citizens that require local manufacturing in order to qualify. The requirements for localization begin with 40% Indonesian parts for two-wheelers in 2023, escalating to 80% in 2026, and 35% Indonesian components for four-wheelers in 2021 escalating to 80% by 2030 (Carol 2019). Indonesia's policy may be partially responsible for international companies like Toyota, Hyundai, and the Chinese battery company GEM investing in the country, although nickel and cobalt reserves may play a role as well (Potkin 2019). Those metals are key components of the popular nickel manganese cobalt lithium-ion EV traction battery (Battery University 2020).

### **2.6.3 Philippines**

In 2006, the Philippine government issued Executive Order 488, which eliminated tariffs for alternative fuel vehicle parts (including electric, hybrid, flexible fuel, and compressed natural gas motor vehicles) (Republic of the Philippines Tariff Commission 2006). This reduction in the cost of parts ultimately contributed to the growth of the EV manufacturing industry. Today, the manufacturing industry for EVs is quite mature. There are 28 manufacturing firms along with 11 parts and components manufacturers and 7 importers. The production market outlook for EVs has correspondingly increased over the years (Industry.gov n.d.).

### **2.6.4 Vietnam**

Vietnamese support for EVs has focused primarily on a reduced excise tax of 5-15% instead of 35-90% for petroleum based vehicles (Ngo Thieu Phong 2017). While EV penetration rates remain low in Vietnam thus far, a few companies are attempting to take advantage of these incentives and produce vehicles in the country. In 2018, Korean-based MBI Group partnered with DKBike, a Vietnamese company, to begin selling electric motorcycles in Vietnam (Ho 2019). In 2019, VinFast took over a Hanoi automotive plant from General Motors and plans to use that platform to become a leading EV manufacturer in Southeast Asia. VinFast has used unconventional approaches to capitalize on national pride, including a vehicle design selection process that incorporated the input of 60,000 Vietnamese

participants. VinFast worked with the Vietnamese government to launch a subsidy program that will significantly reduce the cost of their vehicles (Pastoor 2019).

**Implications for Pakistan:** There are multiple incentive avenues available to jump start the local electric vehicle industry. Policies in Thailand and the Philippines have focused on tax exemptions for EV components for local assembly/repair and manufacturing to spur investment from foreign automakers, and they appear to be succeeding. In contrast, Indonesia has used its local market to attract investment in a similar manner as India by providing incentives to purchase EVs produced locally. At the same time, a Vietnamese company is attempting to capitalize on local incentives and national pride to dominate the domestic EV market.

Pakistan has historically offered incentives to the local auto industry for meeting time-bound 'deletion targets' set by mutual consultation to encourage increasingly greater local content in manufactured vehicles. Some version of this could be used for EV manufacture as well, based on the economics involved.

### 3 Inferences for Pakistan

Countries around the world have instituted various incentive schemes to varying degrees of success. Only Norway has achieved 50% EV penetration in the passenger car market at this point, and only China has achieved a high level of electric two-wheeler penetration (approximately 90% of two-wheeler sales in 2010). However, several lessons from around the globe could be instructive to Pakistan as the nation attempts to replicate this level of success. Table 5 categorizes the policies, provides examples, and describes implications for Pakistan.

**Table 5. Policies, Examples, and Implications for Pakistan**

Category	Policy	Examples	Implications for Pakistan
Vehicle purchase incentives	The extent of financial support significantly influences their impact.	By exempting EVs from several taxes, Norway created first-cost parity with gasoline vehicles, and EVs account for nearly half of car sales in their country.	Pakistan's draft NEVP proposes a tax reduction from 17% for conventional vehicles to 1% for EVs. It will be particularly effective for vehicle segments where this creates price parity for EVs.
	Rolling incentives back too early can drastically affect EV sales. It might be prudent to include a gradual phaseout of incentives as part of the initial policy announcement.	Reducing rebate levels in China, the United Kingdom, and some U.S. states immediately slowed EV sales. The national U.S. policy ramps down income tax credits over the one-year period beginning the second quarter after a given manufacturer sells over 200,000 EVs. Lower sales from Tesla and Chevrolet suggest that this might still be too quick.	Incentives should be adjusted gradually and track a similar reduction in the price of EVs by vehicle segment in order to maintain a successful EV market in Pakistan.
	The type and immediacy of incentives are important as well.	Research from the United States shows that rebates are more effective than sales tax waivers, which in turn are more effective than income tax credits that arrive much later.	Direct and marketable rebates will be more effective than delayed incentives.

Category	Policy	Examples	Implications for Pakistan
	Incentives can be customized for specific vehicle sectors, such as two-wheelers and buses.	India set separate incentives levels for two-wheelers, three-wheelers, four-wheelers, and buses that have been more successful in the two-wheeler market than with four-wheelers.	Pakistan may want to prioritize two-wheelers as the largest vehicle segment in the country and buses due to the their heavy utilization patterns.
	Reduced excise taxes can effectively incentivize EV sales.	Norway and Vietnam both relied on reducing high taxes on vehicles to incentivize EV sales; Norway has achieved much higher EV market penetration, likely due to higher base vehicle taxes and income levels.	Excise tax reduction is the mechanism that Pakistan considers in the draft NEVP.
Fuel prices	Higher gasoline prices and taxes may be good predictors of EV sales.	Higher gasoline prices and taxes were significantly correlated with EV sales in the United States	Gasoline prices in Pakistan are less than half of average global prices. An increase in gasoline prices would incentivize EV adoption.
	Electricity charging discounts might not be the most effective incentive for EV adoption.	Research in the United States found that residential electricity charging discounts were not correlated with EV sales.	Electricity prices are already discounted for residential and commercial customers in Pakistan. Additional discounts for EV charging may not be the most effective incentive.
	EV efficiency improvements may not be correlated with EV acquisitions, perhaps because larger vehicles are both more appealing to consumers and less fuel efficient.	Korean consumers did not appear to be motivated by fuel economy improvements.	Domestically produced EVs should account for local fuel economy sensitivity and environmental implications.

Category	Policy	Examples	Implications for Pakistan
	Carbon taxes must be sufficiently high to influence EV sales.	A carbon tax of approximately \$3/ton in China was not sufficient to make a major difference in terms of EV adoption.	Token carbon taxes are likely insufficient to significantly EV market penetration, but higher prices might be more effective.
	Lost fuel tax revenue from increased EV sales may be offset by different sources. Road usage fees in the form of dynamic VMT taxes are particularly appealing.	Norway and the U.S. state of Oregon are piloting VMT taxes; Norway's tax incorporates dynamic pricing that accounts for vehicle emissions, axial load, population density, and time of day.	VMT taxes can displace the lost revenue from gasoline taxes.
<b>Sales mandates</b>	Mandates on automakers can meet political push-back that undermines their effectiveness. However, the mandates may become increasingly important in the future as governments attempt to displace the burden to subsidize EVs.	The ZEV mandate in California was renegotiated several times between 1990 and 2010, when automakers finally introduced mass market EVs.	Mandates on automakers may result in political opposition, while incentives for EVs are seen more favorably by manufacturers.
<b>Access limitations</b>	Outright bans on petroleum-based vehicles appear to significantly impact market penetration.	After several Chinese cities banned petroleum-fueled two-wheelers and gave electric two-wheelers access to bicycle lanes, electric options gained 90% of the motorized two-wheel market share.	An outright ban on petroleum-based vehicles might not be politically feasible in the near term.
	Special access to lanes normally reserved for buses, high-occupancy vehicles, or bicycles can spur EV adoption.	In Norway, bus lane access was a successful usage-based incentive. In the United States, granting EVs access to high-occupancy vehicle lanes was very effective in spurring EV adoption.	Provided the authorities create and enforce lane restrictions, Pakistan may be able to provide lane access to EVs for congested segments of various motorways.

Category	Policy	Examples	Implications for Pakistan
Domestic EV industry	Localization rates can increase local market share.	India and Indonesia require an increasing percentage of EVs be produced domestically to qualify for generous grants.	Pakistan should compare localization levels from other countries, such as India and Indonesia, when determining appropriate levels.
	Reducing tariffs on EV parts can increase EV production.	Thailand and the Philippines offer incentives to automakers such as tariff elimination on EV parts, corporate tax exemptions, and raw material privileges.	Foreign investors are heavily motivated by incentives, but those incentives result in lost revenue to the country.
	Loans and liquidity can incentivize EV manufacturing.	Korea relied heavily on liquidity support and loan guarantees to help domestic manufacturers successfully compete on a global scale.	Pakistan is considering lower financing rates from the state bank for domestic EV manufacturing in its NEVP.
	Locally produced EVs can capture market share over foreign competitors.	The Hyundai Ioniq and Kia Niro in Korea, Tesla Model S and Model 3 in the United States, and models from BAIC and BYD in China have captured large portions of the local market share.	Local vehicles are often popular options in domestic markets.
Charging infrastructure	Availability of public charging stations is an important driver of EV adoption as well, although public charging needs vary based on the availability of private charging.	Charging infrastructure is particularly important to early adopters in the United States. The 2021 International Energy Conservation Code requires making charging available in multifamily units and at businesses.	Public charging should be customized for particular vehicle segments.
	Private charging is important to fleets.	India's FAME-II offers incentives to bus fleets for charging infrastructure.	Private charging incentives may be particularly important for buses.

Financial incentives for vehicle purchases have been important, and the extent of financial support significantly impacts their efficacy (Axsen and Wolinetz 2018). By exempting EVs from several taxes, Norway created first-cost parity with gasoline vehicles, and EVs account for nearly half of car sales in their country. Rolling incentives back too early can drastically affect EV sales. Reducing rebate levels in China, the United Kingdom, and elsewhere immediately slowed EV sales. It would be prudent to include a gradual phaseout of incentives as part of the initial policy announcement such as the national U.S. policy to ramp down income tax credits when a given manufacturer sells over 200,000 EVs. The reduction in incentives could be linked to an external metric, such as lithium-ion battery prices or vehicle prices. The type and immediacy of incentives are important as well. Research from the United States shows that rebates are more effective than sales tax waivers, which in turn are more effective than income tax credits that arrive much later.

One of the more surprising results from the literature was that discounted electricity rates for EVs in the United States were not significantly correlated with EV sales; however, higher gasoline prices and taxes were both tied to EV market penetration. This is counter-intuitive because both impact the total cost of ownership comparison between EVs and gasoline vehicles. Similarly, research in Korea indicated that consumers were not motivated by fuel economy improvements. It is possible that consumers are more aware of gasoline than electricity rates or fuel economy, and fuel economy is inversely related to vehicle size which may be a more important factor in consumer decision-making. Carbon taxes are another method to raise gasoline prices, which may induce a switchover to EVs. With low international oil prices in the first half of 2020, taxes might be more politically palatable at present than at other times.

As the world moves to higher electric vehicle penetrations, many administrations are wondering how declining fuel taxes will affect their revenues. Even at lower penetrations of EVs, other drivers complain of about EVs not paying their share of road maintenance. Charging vehicle owners based on VMT instead of fuel purchased appears to be a promising solution. A VMT-based program could further mitigate congestion and promote environmental benefits by accounting for these factors in the fees charged and alerting drivers about construction, congestion, even parking space availability.

Goals or mandates for EV sales alone have not appeared to create a market for EVs without supporting policies, although embedded credits and trading mechanisms can shift the responsibility for developing EV markets to automotive manufacturers (Hardman et al. 2018). The ZEV mandate in California existed for two decades before EVs entered the mainstream marketplace there. The NEV mandate in China was paired with financial incentives. When those incentive levels were reduced, EV sales quickly fell; however, the mandates may become increasingly important in the future as governments attempt to displace the burden to subsidize EVs and EVs become more cost competitive with more affordable, higher-quality energy storage systems.

Providing EVs with special access while banning similar petroleum vehicles appears to significantly impact market penetration. After several Chinese cities banned petroleum-fueled two-wheelers and gave electric two-wheelers access to bicycle lanes, electric options gained 90% of the motorized two-wheel market share. In the United States, granting EVs access to high-occupancy vehicle lanes was very effective in spurring EV adoption.

Fostering a domestic EV market is an important goal in countries competing for automotive market share, such as India, Indonesia Korea, Thailand, the Philippines, and Vietnam. India and Indonesia accomplishing this goal by requiring that an increasing percentage of EVs be produced domestically to qualify for generous grants. Korea offers its automotive manufacturers liquidity support and loan guarantees to help them compete on the global scale. Thailand and the Philippines incentivize manufacturing through exemptions from corporate taxes and import tariffs. In these cases, the efforts appear to be successful. Indian and Indonesian manufacturers, through partnerships with foreign



companies or independently, are selling EVs locally, and Korea, Thailand, and the Philippines are exporting EVs abroad. Vietnam is in the earlier stages of EV industry incentivization, but they have fostered a local company that is catering to the Vietnamese market. Domestically produced vehicles in Korea, China, and the United States have captured large portions of the EV market share, so this may be a prudent strategy.

Availability of public charging stations is an important driver of EV adoption as well, although public charging needs vary based on the availability of private charging. This likely applies to different vehicle classes in Pakistan. For example, India's FAME-II program provides additional incentives directly to bus operators for charging infrastructure, while the United States offers an income tax credit to private enterprises for the installation of publicly available charging infrastructure. Electric two-wheelers will require charging infrastructure as well, although the power requirements for each unit will be small. Transitioning a significant percentage of the 12 million two-wheelers in Pakistan would require adopting something similar to the 2021 International Energy Conservation Code that requires making charging available in multifamily units and at businesses.

In order to determine the quantifiable impact of each policy mechanism after controlling for relevant factors and other policies, a quantitative modeling approach could be undertaken as subsequent research.

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