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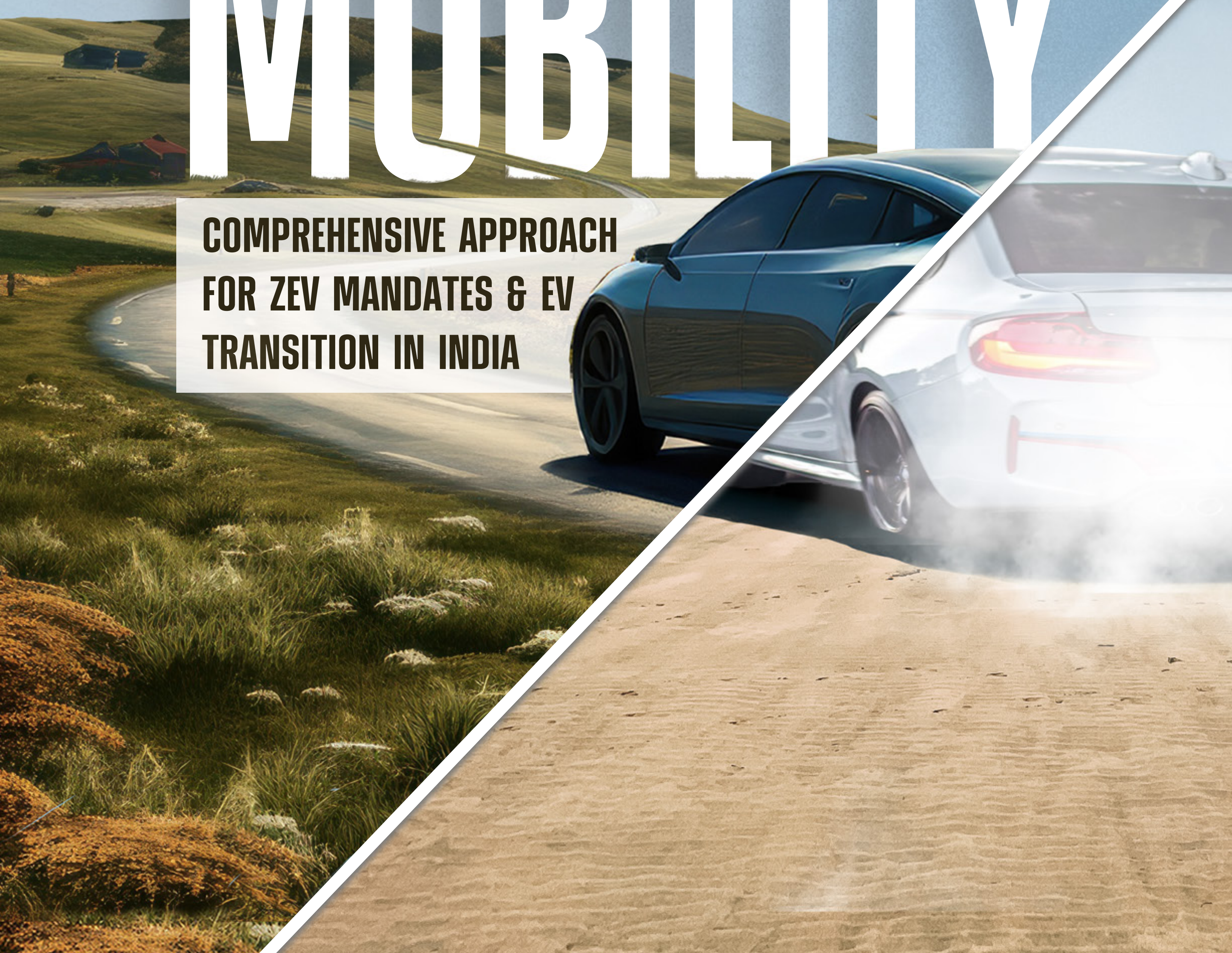
PATHWAYS TO ELECTRICAL MOBILITY

COMPREHENSIVE APPROACH FOR ZEV MANDATES & EV TRANSITION IN INDIA



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Pathways to Electrical Mobility

Comprehensive Approach for ZEV Mandates & EV Transition in India

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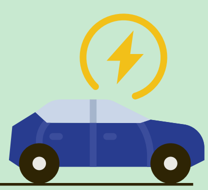
Introduction: EV Mobility and ZEV Mandate

Economies around the world have initiated strategic efforts to promote electric mobility, a pivotal response to escalating concerns over climate change, air pollution, and reliance on oil imports, and to secure a vantage point within this emerging sector. The transportation sector is expected to become the fastest-growing source of greenhouse gas (GHG) emissions, with forecasts indicating that it could exceed 30% of the total GHG emissions in the coming years. In this context, the adoption of electric vehicles (EVs) emerges as a compelling alternative. (United Nations, n.d.; United Nations, 2015). Major economies in the world have undertaken significant steps in this direction evident in the implementation of consumer-centric incentives, production incentives, and Zero Emission Vehicle (ZEV) mandates. The shift toward EVs has been swift, spurred by diminishing costs in certain established markets.

It is reported that electric vehicles constituted

10%



of global passenger vehicle sales, a tenfold increase from previous years.

Notably, Norway leads with 80% of passenger vehicle sales being all-electric in 2022, followed by Iceland (41%), Sweden (32%), the Notably,

Norway leads with 80% of passenger vehicle sales being all-electric in 2022, followed by Iceland (41%), Sweden (32%), the Netherlands (24%), China (22%), the European Union (12%), and the United States (6%). The adoption trajectory in most economies exhibits an S-curve growth pattern, indicative of an exponential adoption rate that accelerates once cost parity with conventional vehicles is achieved. India, albeit starting from a lower base, is advancing along this curve at a rate threefold that of the global average (as of 2021-22).

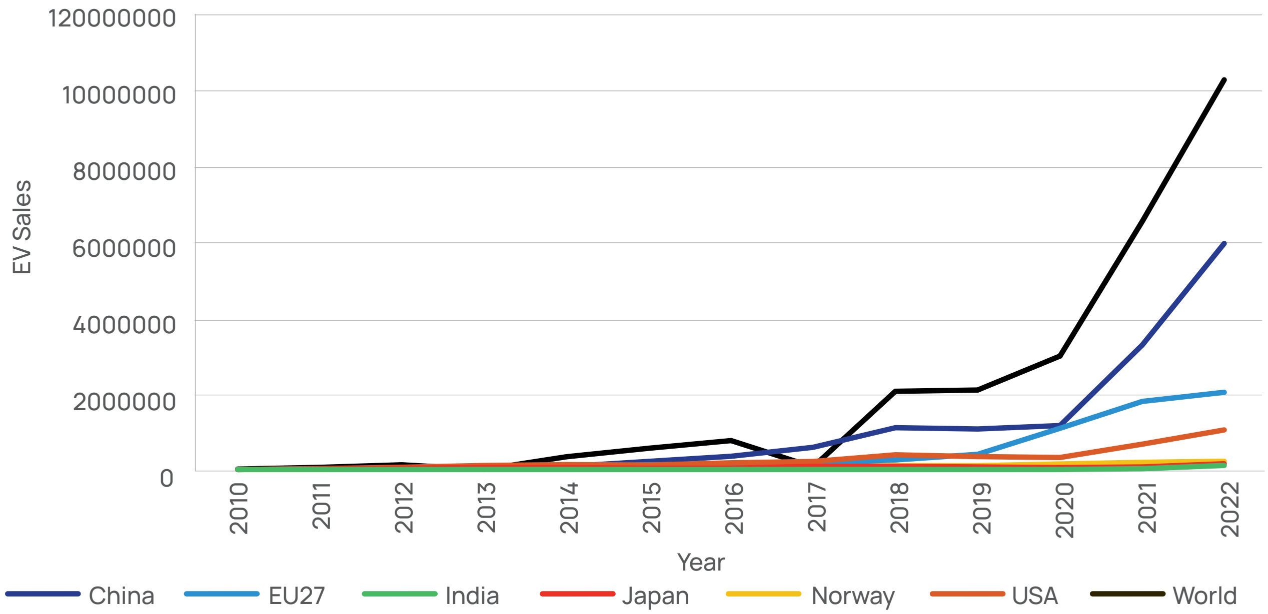
Only those economies with a well-established electric vehicle (EV) market, exhibiting high penetration rates, have managed to sustain the

75-95%

growth rate considered essential for meeting established climate goals

This robust growth is the main contributor to the high global average. In contrast, countries such as India and Japan lag behind in achieving the necessary growth rates (Figure 1) (Jaeger, 2023; IEA, 2023; Climate Action Tracker, 2020).

Figure 1- EV Sales as a Share of Passenger Vehicle Sales

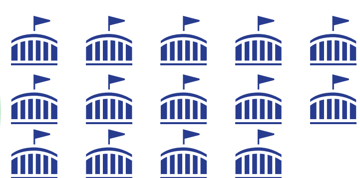


Source - Jaeger, 2023; IEA, 2023; Climate Action Tracker, 2020

The push for EVs is gaining momentum, driven by clear goals and cooperative initiatives at both national and international levels.

On the National Level

More than 14 governments



have their own ZEV targets to phase out ICE vehicles (ZEV Transition Council, 2023) (Figure 2).

There have been several recent multilateral agreements that are aiding a collective movement in the transition. The Drive to Zero Program[1] was one of the pioneering zero emission-centric agreements. This effort was strengthened at the Conference of the Parties (COP) 27 meeting, where the Accelerating to Zero (A2Z)[2] coalition that builds on the Zero-Emission Vehicles Declaration was launched.

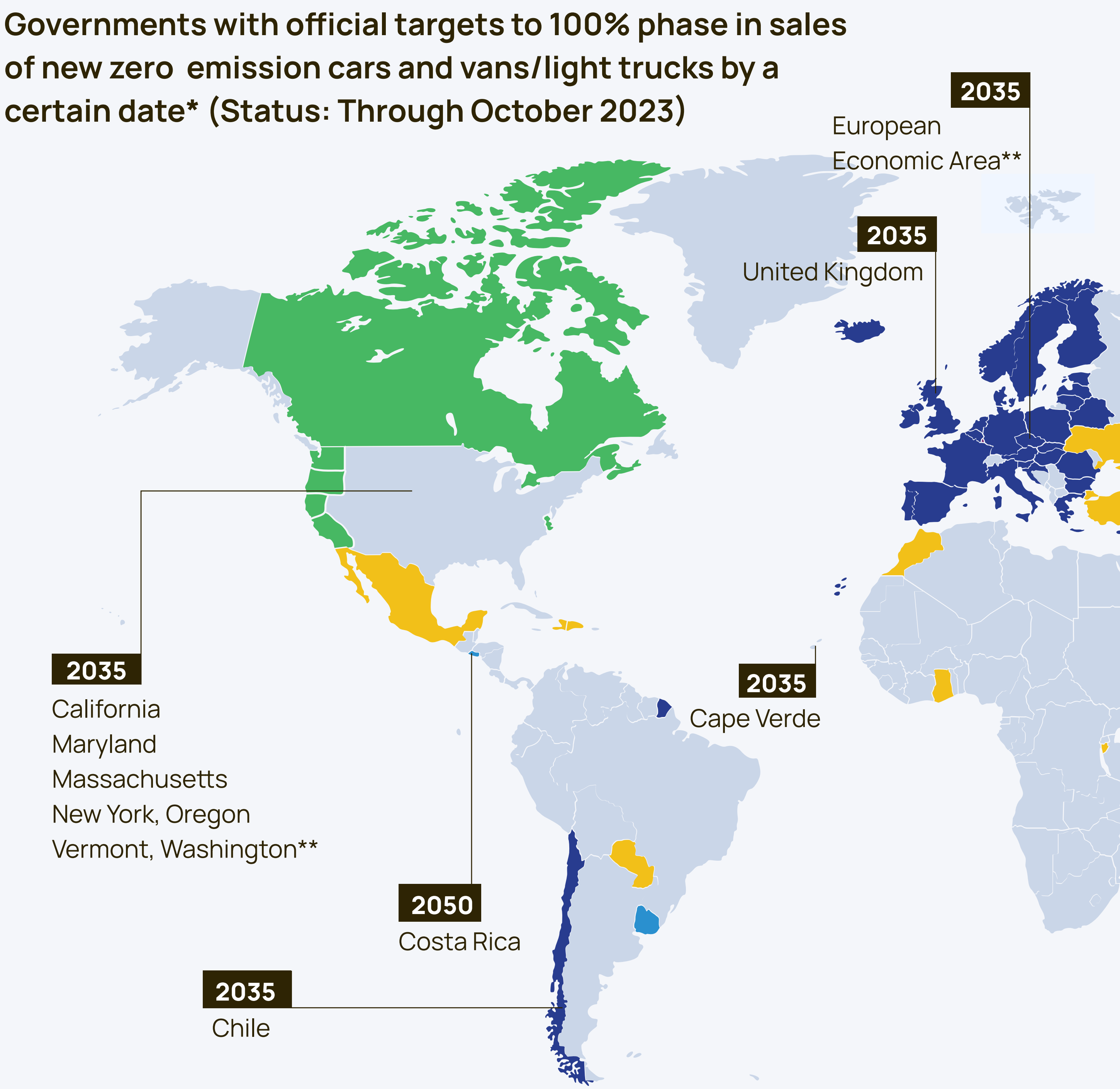
The World Business Council for Sustainable Development (WBCSD) also took a significant step at COP 27. They launched an initiative to encourage more collaboration in rapidly developing economies to speed up the move to zero-emission road transport. In 2022, the Climate Group started the EV100+ campaign. This

[1] This program was initiated by the Dutch Government, set a strong example in 2021 by starting a global agreement aimed at making all new buses and trucks zero-emission by 2040, and at least 30% by 2030 which was signed by 27 signatories.

[2] With 233 signatories, the coalition is dedicated to switching all new cars and vans to zero emissions by 2040. These 233 signatories include 30 governments in advanced economies, 11 governments in EMDEs, 73 local/regional governments, 14 automotive manufacturers, 47 fleet owners and operators, 15 investors with shareholdings in automotive manufacturing, 2 financial institutions and 31 other signatories. India is one of the 11 EMDEs that are part of this coalition (Source: IEA)

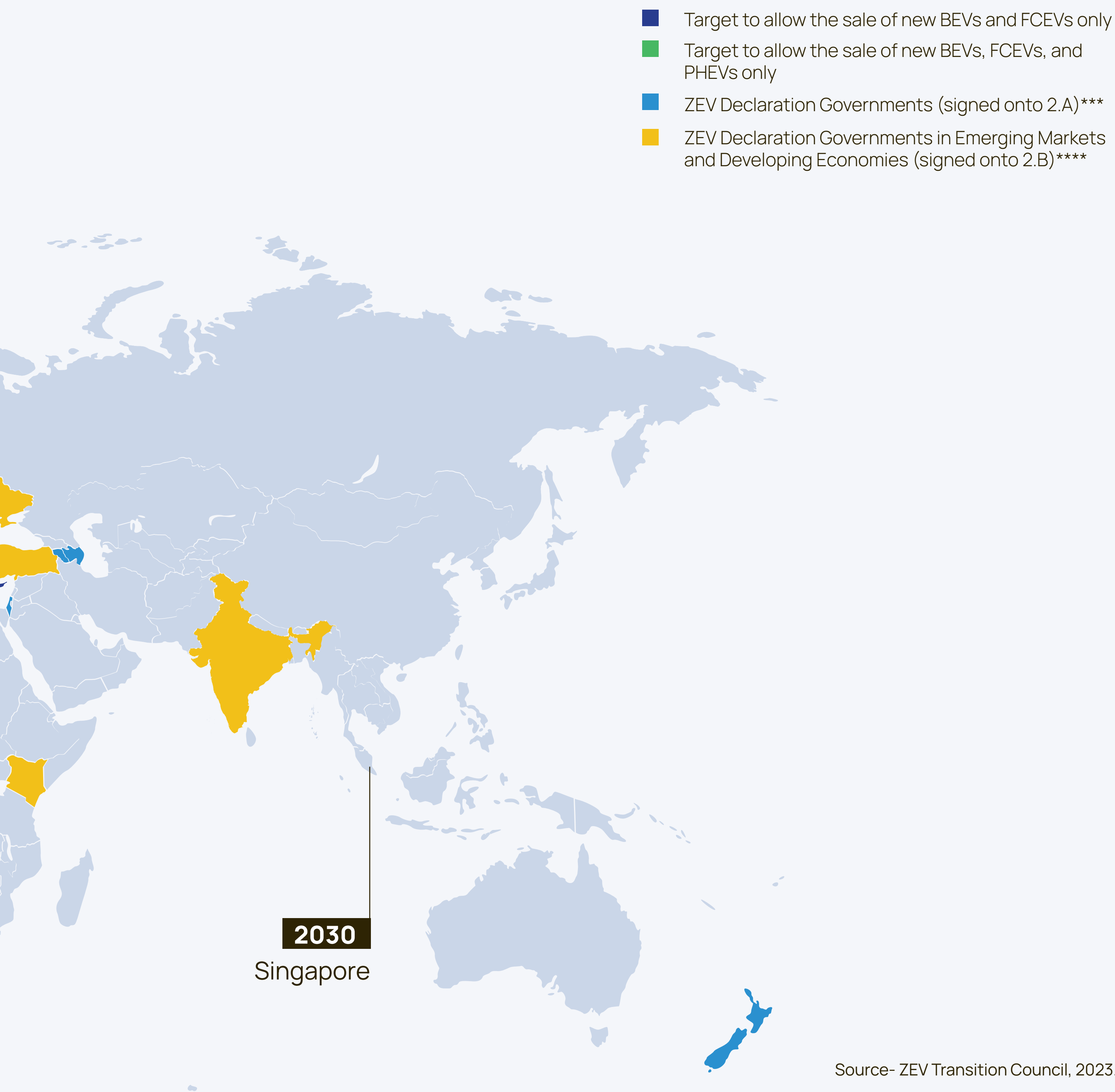
campaign focuses on major markets, including Organisation for Economic Co-operation and Development (OECD) countries, China, and India, committing to make all large vehicles in their fleets zero-emission by 2040. Along with this, in 2022, acknowledging the pivotal influence of national governments through demand signals and leadership, a group of nine (9) countries committed to the Zero Emission Government Fleet Declaration. They aim to reach 100% zero-emission cars and vans in government fleets, with an additional aspiration of 100% zero-emission trucks and buses, by no later than 2035. It has become increasingly clear that ZEV mandates and targets have become the cornerstone of the EV transition. These recent initiatives, alongside earlier targets and endeavours have not only sustained but also significantly amplified the prominence of these nations in the global EV market. (IEA, 2023)

Figure 2- Targets for EVs across the Globe.



* Includes countries, states, and provinces that have set targets to only allow the sale or registration of new battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs), and plug-in hybrid electric vehicles (PHEVs). Countries such as Japan with pledges that include hybrid electric vehicles (HEVs) and mild hybrid electric vehicles (MHEVs) are excluded as these vehicles are non plug-in hybrids.

** The Canadian province of British Columbia has a regulation to enforce its 2040 target, as do California, Maryland, Massachusetts, New York, Oregon, Vermont, and Washington for their 2035 targets. The European Union (EU) also has a regulation enforcing its 2035 target; it is applicable to the member states of the European Economic Area (EEA), that is the 27 EU member states



Source- ZEV Transition Council, 2023.

and, pending adoption by the EEA Joint Committee, to some or all EEA European Free Trade Association (EFTA) states, which include Iceland, Liechtenstein, and Norway. Norway has set a 2025 phase-in target and Austria,Denmark, Greece, Iceland, the Netherlands, and Slovenia have set 2030 phase-in targets, but those are not binding.

*** Zero-Emission Vehicle (ZEV) Declaration signatories to 2.A committed to phase-in targets by 2035 for leading markets and by 2040 globally. Countries with existing official targets (binding and non-binding) are not separately highlighted, including Austria, Belgium, Canada, Cape Verde, Chile, Croatia, Cyprus, Denmark, Finland, France, Greece, Iceland, Ireland, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Slovenia, Spain, Sweden, and the United Kingdom.

**** Zero-Emission Vehicle (ZEV) Declaration signatories to 2.B committed to work intensely toward accelerated proliferation and adoption of zero-emission vehicles.

India, as a proactive participant in global efforts towards environmental sustainability,

has made noteworthy commitments.

While the country had pre-existing policies with a focus on electric mobility, the recent commitment made at the COP26 summit in 2030 has injected a renewed sense of urgency and purpose into its decarbonisation strategy. This pledge signifies a significant acceleration in India's efforts towards achieving its environmental goals. This plan includes an ambitious target to reduce carbon emissions by 50% within its energy sector and to achieve a robust renewable energy generation capacity of 500 gigawatts by the end of the decade.

The National Auto Policy (NAP) 2018, for instance, sets forth Corporate Average Fuel Economy (CAFE) standards extending through 2025 and mandates compliance with Bharat Stage VI (BSVI) emissions regulations. Concurrently, the National Electric Mobility Mission Plan (NEMMP) 2020 is designed to bolster annual sales of hybrid and electric vehicles, targeting six to seven million units starting in 2020. Under the NEMMP umbrella, the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles schemes (FAME I and II) were developed to lower the acquisition costs of these vehicles, thereby incentivizing consumer purchase on the production front,

two Production Linked Incentive (PLI) Schemes were introduced, focusing on the automobile sector: one for advanced chemistry cells (ACC) and another for advanced automotive technology (AAT) products. These two PLI schemes aim to establish a competitive ACC and EV manufacturing in the country.

Additionally,

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states and UTs have policies focusing on EVs, which significantly contributes to the promotion of EV adoption and the encouragement of innovation (PHDCCI, 2024)., offer exemptions on road taxes, enhance charging infrastructure, and provide subsidies for services such as retrofitting and electricity costs. As a result of these efforts, the penetration of EVs in India is increasing.

Currently, two-wheeler (2W) EVs form the majority of EV sales today, accounting for 85%–90% of all EV units sold in India, followed by four-wheeler (4W) EVs (7%–9% of sales) and three-wheeler (3W) EVs (5%–7% of sales) (Seetharaman, et al., 2023). Penetration of EVs is also led by 3-wheelers, with 8% penetration, followed by e-buses at 7%, e-2W at 5%, and electric passenger vehicles hovering around 1% of the total sales respectively. By 2023, r-rickshaws, constituting 90% of the 3Ws, achieved a penetration rate of 53%, driven by factors such as accessibility, low maintenance costs, advancing technologies, and the growing demand for efficient passenger transportation (Vahan Dashboard, 2023) (Economic Times, 2023).

When these developments are juxtaposed with India's ambitious 2030 goals and the broader climate change imperatives, it becomes evident that the country is trailing on the anticipated trajectory, which necessitates a recalibration of policy frameworks. There is an absence of a coherent national directive on EV adoption has resulted in a misalignment of initiatives, impeding the country's ability to fully capitalize on the potential benefits of its EV policies. Like other nations, the adoption of a ZEV target can be instrumental in synchronizing fragmented policy efforts across various sectors and states, channelling them toward a unified economic objective. To construct policies that address the blind spots that may impede India's progress towards its envisioned sustainable transportation objectives a deeper analysis of best practices from global leaders in EV adoption, coupled with an in-depth examination of the Indian ecosystem, is imperative.

Outline of the Report.

The current report is structured in following sections:

01 Global Overview of Implemented ZEV Policies:

Conduct an in-depth review of successful ZEV policies implemented across nations. This section will provide a comprehensive analysis, drawing comparisons between different global economies and their respective policies.

02 India's Automobile Sector: Current Landscape

Explore the current landscape of India's automotive industry, emphasizing the evolution of electric mobility policies. This section aims to offer a detailed evaluation of the industry's current standing and its alignment with the broader objectives of sustainability.

03 Examining India's Automotive Value Chain:

Undertake a meticulous examination of India's automotive value chain, encompassing component and structural analyses. This segment will pinpoint policy gaps that pose barriers to EV adoption, shedding light on areas requiring strategic intervention.

04 Integration of ZEV mandate in Indian Economy: Model Simulation

This section studies the readiness of the Indian ecosystem for the ZEV mandate and analyses the major reasons for the success of the ZEV mandate in China. It develops a robust model designed to assess the feasibility of integrating a ZEV mandate in India, aligning with the nation's electrification targets set for 2030. This model will serve as a tool to gauge the potential impact if a ZEV mandate comes into play and its impact on the Indian automotive landscape. It elaborates on the substantial challenges faced due to data constraints, limited report period, and uncertainties in manufacturing costs during the construction of the model.

05 Key Learnings and Way Forward

This section outlines the key takeaways of this pioneering report on implementing a ZEV mandate in India.


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Global Overview of Implemented ZEV Policies

It is evident that in the run for limiting global temperature increase and reducing the impacts of climate change and air pollution, especially in low- and middle-income countries, correcting the transport emissions trajectory and undertaking a global shift towards zero-emissions electric mobility is crucial (United Nations, n.d.; United Nations, 2015).

Global electric markets currently exhibit variations in the levels of policy support, corporate initiatives, and consumer preferences and behaviours. The impact of policy is particularly significant, as it actively shapes strategies to promote the extensive adoption of electric mobility and facilitates the involvement of consumers. An incremental implementation of a nuanced combination of policies, which strikes a balance between manufacturer-centric and consumer-centric approaches, has taken place in key markets including China, Europe, and the United States. Complementing the judicious use of direct and indirect incentives, these policies establish targets for EVs by implementing ZEV mandates (IEA, 2023).

The Zero Emissions Mandate (ZEV) mandate is a governmental regulation designed to accelerate the adoption of Electric Vehicles and other zero-emission vehicles by requiring automakers to produce and sell a certain percentage of these vehicles. Originating in the United States with California's adoption, the ZEV mandate has subsequently been emulated in various forms by multiple economies. The specific targets set by each country are tailored to their unique economic framework and the structure of their automotive sectors. These targets, which may focus on the electrification of vehicle sales, the existing fleet, or public transportation systems, are strategically aligned on a timeline that best fits the nation's ambitions for climate change mitigation and the transition towards electrification (Table 1). ZEV targets have become a cornerstone of policy for transport and decarbonisation.

Table 1- Global Zero-Emission Vehicle Mandates and Internal Combustion Engine bans.

Target Year	Country	Type of Target	Type of Vehicle
2025	Norway	100% ZEV Sales	LDV
	Denmark	100% ZEV Public Buses Sales	HDV
	Ecuador	100% ZEV Public Buses Sales	HDV
2030	Iceland	100% ZEV Sales	LDV
	Austria	100% ZEV Sales	LDV
	Netherlands	100% ZEV Sales	LDV
	Israel	100% ZEV Sales	LDV
	Ukraine	100% ZEV Sales	LDV and HDV
	Slovenia	100% Electrified Sales	LDV
	United Kingdom	100% Electrified Sales	LDV
	Singapore	100% Electrified Sales	LDV
	Netherlands	100% ZEV Public Buses Stock	HDV
2035	United States	100% ZEV Sales	LDV
	Italy	100% ZEV Sales	LDV
	Cabo Verde	100% ZEV Sales	LDV
	Canada	100% ZEV Sales	LDV
	EU	100% ZEV Sales	LDV
	United Kingdom	100% ZEV Sales	LDV
	Austria	100% ZEV Sales	HDV
	Japan	100% Electrified Sales	LDV
	Chile	ICE ban and 100% ZEV Public Bus Sales	LDV and HDV
	Columbia	100% ZEV Public Bus Sales	HDV
	New Zealand	100% ZEV Public Buses Stock	HDV

LDV= Light Duty Vehicle, HDV= Heavy Duty Vehicle

Target Year	Country	Type of Target	Type of Vehicle
2040	Argentina	ICE ban	LDV
	Sri Lanka	100% Electrified Stock	LDV
	Cabo Verde	100% ZEV Sales	HDV
	Canada	100% ZEV Sales	HDV
	United Kingdom	100% ZEV Sales	HDV
	Singapore	100% ZEV Public Buses Stock	HDV
2045	Chile	100% ZEV Sales	HDV
2050	Costa Rica	100% ZEV Sales	LDV and HDV
	Mexico	100% ZEV Sales	LDV and HDV
	Dominican Republic	100% ZEV Public Buses Stock	HDV
	Israel	100% ZEV Public Buses Stock	HDV

LDV= Light Duty Vehicle, HDV= Heavy Duty Vehicle

Source- IEA, 2023.

Before stepping into understanding the efficacy of such a mandate in the Indian context, a deeper dive into the ZEV mandate's evolution and its effective implementation in leading economies is imperative to understand its impact on accelerating the shift towards sustainable mobility.

2.1 United States of America - Pioneer of the ZEV Mandate

The introduction of the California ZEV rule issued by the California Air Resources Board (CARB) in 1990 was one of the most impactful and revolutionary policies focusing on air quality and vehicular emission policies. During the late 1980s, both government entities and the automotive industry began to recognize that the potential for reducing emissions from traditional gasoline-powered combustion engines was nearing its maximum. This realization led to an investigation into alternative fuels and the development of new drivetrain technologies to achieve the demanding air quality standards set forth. Los Angeles and the South Coast Air Quality Management District, recognizing the potential of battery electric vehicles (BEVs) to address regional air quality challenges, initiated proposals as early as 1988 for the mass deployment of BEVs. Despite scepticism about its feasibility, the ZEV mandate endured as a segment of the influential Low Emission Vehicles and Clean Fuels Program, which set rigorous emission standards for automakers and alternative fuel mandates for oil companies (Collantes & Sperling, 2008). The policy is intended to be "technology forcing", i.e. to drive innovation in electric technologies and scale up battery production to reduce costs, setting a performance standard for selling vehicles with zero emissions, that could be met only by battery EVs or fuel cell vehicles (McConnell & Leard, 2021).

The mandate has undergone several modifications in order to evolve with the changing technologies and cost dynamics. The mandate can be studied in three phases:

Phase 1 (1990-2004)

The ZEV mandate was first introduced in the US in 1990. The ZEV mandate initially stipulated that 2% of newly manufactured vehicles from prominent manufacturers must be ZEVs by

1998. This percentage subsequently increased to 5% in 2001 and further to 10% in 2003. CARB implemented further modifications, such as the incorporation of partial ZEV (PZEV) certificates in 1998 to recognise vehicles that emit less but are not purely emission-less (Collantes & Sperling, 2008). Yet manufacturers and policymakers realised that the rate of technological advancement, consumer cost, and infrastructure were not harmonious after a decade of unfulfilled objectives. This realisation prompted a modification in the mandate and the implementation of consumer-side incentives, such as tax incentives. Several manufacturers sued CARB in 2003 and 2004 challenging the viability of these mandates, despite the modifications, which resulted in the prohibition of ZEV mandates (McConnell & Benjamin, 2021).

Phase II (2005-2014)

A new ZEV mandate in 2005 came into effect leading to innovations in electrification and the introduction of newer models. In addition, the credit trading system that allowed manufacturers to comply with the mandate by buying and selling credits in addition to the manufacture of EVs was formalized in 2010 (McConnell & Benjamin, 2021).

In January 2012, the California Air Resources Board (CARB) implemented the Advanced Clean Cars program, setting ambitious targets for electric-drive vehicle sales to exceed 10% by 2025. This program was further bolstered by an advanced ZEV initiative, aiming for a significant milestone of 1.5 million ZEVs on California's roads by 2025 as a means to enhance environmental sustainability, economic growth, and overall life quality in the state. Around 2011, fully electric vehicles by Tesla and Nissan began to enter the market. By February 2013, an interagency working group, orchestrated by the Governor's Office, unveiled a detailed ZEV Action Plan. This roadmap outlined the specific actions to meet the 1.5 million ZEV goal, broadening the definition of ZEVs to encompass hydrogen Fuel Cell Electric Vehicles (FCEVs), Battery Electric Vehicles (BEVs), and Plug-in Hybrid Electric Vehicles (PHEVs). Additionally, several states have aligned with California's rigorous environmental stance, like New York, Massachusetts, Vermont, Maine, Connecticut, Rhode Island, New Jersey, Oregon, and Maryland.

Phase III (2018-2025)

The ZEV mandate was adopted for model years 2018-2025, imposing increasingly stringent credit requirements ranging from 4.5% in 2018 to 22% in 2025. CARB distinguishes between "large-volume manufacturers" and "intermediate-volume manufacturers." Although both categories face identical percentage credit requirements, they differ in the types of vehicles that qualify to meet these requirements. CARB projects that the ZEV mandate program will contribute to achieving a ZEV market share of approximately 8% by 2025. (ICCT, 2019)

In 2022, CARB formulated Advanced Clean Cars II standards for the post-2025 era. With this CARB's vision is to achieve a full transition to EVs by 2035, with a proposed sales composition entirely comprised of EVs, including BEVs, FCEVs, and PHEVs—the latter with at least a 73-mile all-electric range per two-cycle tests and the capability for 40 miles under the US06 driving cycle. Limitations have been placed on PHEVs, restricting them to a maximum of 20% of the annual EV sales quota. These regulations present two potential pathways to incrementally reach the EV sales targets, with one scenario considering the possibility of achieving only a 70% target by 2035. Washington, Delaware, Colorado, Minnesota, Nevada, and Virginia, are anticipated to comply with these progressive ACC II ZEV regulations, marking a nationwide commitment to cleaner automotive standards and sustainable transportation (TransportPolicy, n.d.; California Air Resources Board, 2022).

Several supportive incentives have been undertaken to aid the ACC II ZEV and improve access to ZEVs for all Californians, including moderate- and low-income consumers. These include:

01 Clean Cars 4 All

(allocation of USD 400 million over three years)

Offers up to USD 9,500 for low-income motorists who replace their older, less environmentally friendly vehicles with cleaner options.

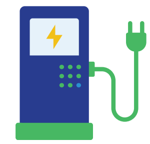
02 The Clean Vehicle Rebate Project (CVRP)

(allocation of USD 525 million)

Provides up to USD 7,000 to income-eligible individuals to purchase or lease a ZEV.

03 The Clean Vehicle Assistance Program

Assists low-income purchasers with preferential financing and up to USD 5,000 in down-payment support for ZEV acquisition.



In addition, USD 300 million is reserved for expanding the EV charging infrastructure, catering especially to those without home charging capabilities.

EVs provide cost savings as a result of reduced fuel expenditures. For instance, home charging for EVs typically costs around half as much as petrol for the same distance. Additionally, EV maintenance expenses are around 40% less than those of vehicles powered by internal combustion engines (Transport Policy, n.d.; California Air Resources Board, 2022). Significant investments in PEV research and charging infrastructure were made under initiatives like EV Everywhere, targeting widespread PEV access by 2022. Additionally, the Inflation Reduction Act, 2022[3] has played a significant role by increasing tax credits for qualifying new and used EV purchases, reducing costs for buyers.

In 2022, registrations for ZEV vehicles reached 3.4 million, capturing a mere 1.2% of the automotive market—a stark contrast to the 276 million gasoline and diesel vehicles (US Department of Energy, 2023). Hence, the newer policies come at a crucial juncture and are evidently in the right direction as projections for 2023 indicate a remarkable surge in electric vehicle sales, potentially achieving 9% of all passenger vehicle sales in the U.S. This marks a considerable rise from the 7.3% recorded in the

[3] The Inflation Reduction Act (IRA) of 2022 aims to reduce domestic Inflation brought by the global energy crisis by reducing carbon emissions by 40% by 2030. For this, IRA includes a combination of grants, loans, tax provisions and other incentives to accelerate the deployment of clean energy, clean vehicles, clean buildings and clean manufacturing. (Source- IEA)

previous year and signifies the first-time annual sales of EVs could surpass the 1 million mark, with projections ranging between 1.3 and 1.4 million vehicles (Voa News, 2023).

Although the U.S. has lagged behind countries such as China, Germany, and Norway in terms of EV adoption rates, the latter has witnessed a significant surge in EV utilisation. The decline in EV prices, primarily due to fierce market competition (especially between Tesla and other manufacturers), has been a significant catalyst for this expansion. As a result, more affordable EV alternatives have become available. The increasing affordability and desirability of electric vehicles have been substantially influenced by technological advancements in battery efficiency and the declining prices of critical materials such as lithium and cobalt.

2.2. China – World's Largest EV Market and Manufacturer

China's commitment to EV has significantly influenced the global market, with its 22% market share equating to 4.4 million sales in 2023—double the international average and more than 3.3 million sales globally (Jaeger, 2023). China has gone through different phases of implementing a plethora of policies before setting New-Energy Vehicle (NEV) mandate policy to steadfast its EV growth.

China initiated its EV initiative in the early 2000s, bolstering its efforts with financial incentives in pilot cities and a broader vehicle portfolio that now includes plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). The aforementioned incentives provided manufacturers with exemptions from purchase taxes, reduced electricity tariffs, and production tax reliefs. The cumulative impact of these measures between 2009 and 2022 was an investment exceeding 200 billion Yuan (approximately USD 28 billion) (Yu, 2023). The evolution of China's EV policies demonstrates a strategic and responsive approach, adapting over time based on the effectiveness of earlier policies. This holistic strategy has been integral to China's success in the EV market.

The extensive path of China leading to the NEV mandate and beyond can be studied in the following three phases.

Phase I (1990-2009)
Foundations for Comprehensive Policy

China's EV research traces back to the eighth five-year plan (1991–1995) when initiatives such as the collaboration between Tsinghua University and Tianjin Automotive Industry Company were sponsored to innovate in an electric bus and mini-car technology. Progressing through the 1990s and into the new millennium, the State Science and Technology Commission embarked on several EV-centric projects under the National Key Technologies R&D Program. This research was designated as a 'Three Longitudes' initiative with a focus on control systems, electric motors, and batteries in the nation's Five-Year Plan as early as 2001 (Li, Yang, & Sandu, Electric vehicles in China, 2018). The appointment of Wan Gang, a former Audi engineer, as the Minister of Science and Technology in 2007 marked a pivotal moment, providing significant impetus to the industry (Yang, 2023). The subsequent introduction of the three-year EV pilot program by the People's Republic of China's Ministry of Finance (MOF) and the Ministry of Science and Technology (MOST) known as the Thousands of Vehicles, Tens of Cities (TVTC) programs aimed to deploy at least 1,000 EVs in selected cities between 2009 and 2012. Initially aimed at public procurement, this endeavour subsequently broadened its scope to encompass private procurement, incorporating manufacturer subsidies and emphasising fuel efficiency in determining subsidy levels (Li, Yang, & Sandu, Electric vehicles in China, 2018).

Phase II (2010-2017)
Evolving Policy Landscape in Response to Technological and Market Dynamics

Since 2010, a series of policy measures have been introduced and implemented by the Chinese government, to boost the penetration rate of EVs. Four central ministries and commissions (namely MOF, MOST, the MIIT, and the NDRC) jointly announced the new three-year EV pilot programs in 2013. These programs were aimed to promote the deployment of a total of 300,000 vehicles in 39 select cities and city groups, over the period 2013–2015. The program's broad scope covered both public and private sectors, providing financial subsidies to spur EV procurement. The subsidy framework had three key components: direct payments to certified automakers, subsidy amounts pegged to the mileage per charge rather than fuel savings, and a structured decrease in subsidies by 5–10% annually. Furthermore, in 2014, the MOF enacted supplementary fiscal incentives, such as exemptions from purchase tax, vehicle registration tax, and reductions in import duties for EV parts and equipment.

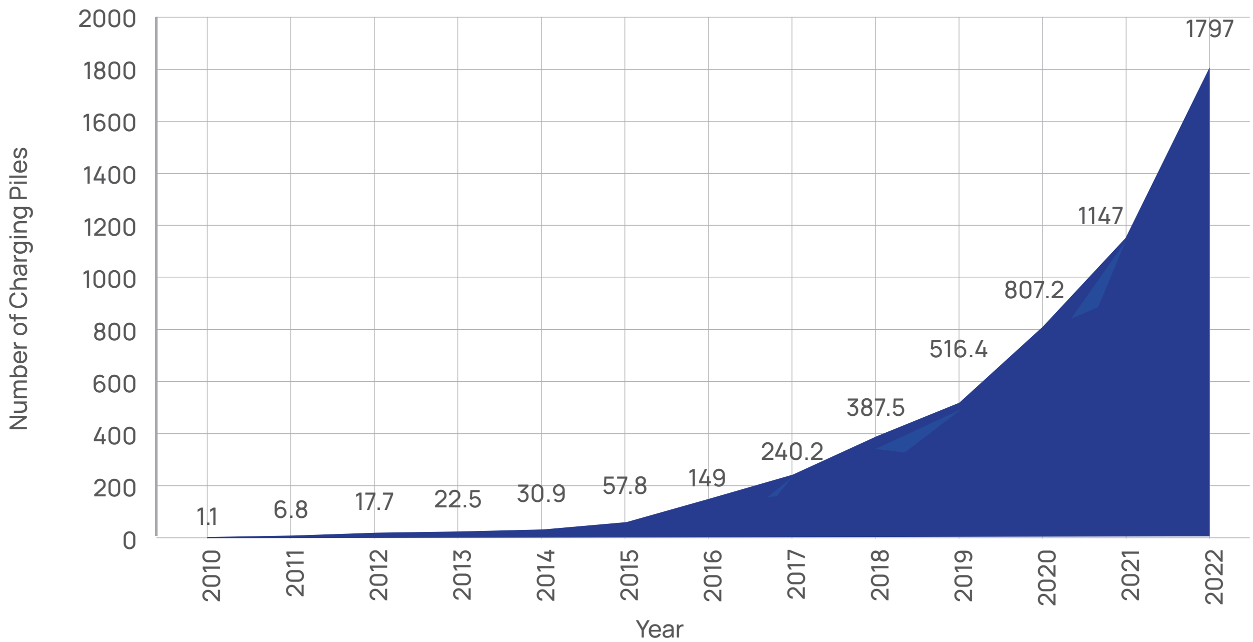
Despite these concerted efforts, the actual production and ownership figures of New Energy Vehicles (NEVs) in 2014, 84,000 and 12,000 respectively, did not meet the ambitious targets set by the Industry Development Plan for Energy Saving and New Energy Vehicles (Li, Long, & Chen, 2016). Additionally, China grappled with multifaceted issues including technological uncertainties and market scepticism on the supply side, and on the demand side, barriers like subpar EV performance, evident in limited driving range and extended recharging times, as well as steep initial costs. Compounding these technical and economic concerns were institutional and socio-political challenges such as decentralized authority, regional protectionism, and policy incentives that inadvertently obstructed cohesive policy formation and execution.

In its second phase, China's strategy pivoted, placing greater emphasis on supply-side measures, and acknowledging the limitations inherent in the previously dominant demand-driven, subsidy-heavy approach. In 2015, four central ministries and commissions (MIIT, MOF, MOST, and the NDRC) jointly extended the programs to its second phase, over the period 2016–2020, with certain changes. Notably, subsidies were considerably reduced (20% in 2017-18, 40% in 2019-20 compared to 2016) and capped for local governments. Additionally, stricter auditing, tougher technical standards (battery density, speed, etc.) and a shift in focus from fuel-saving capacity to driving range for subsidy determination were implemented. There has been a change in the way financial incentives, especially subsidies have changed. In this period, subsidies were determined on the basis of the driving ranges of EVs instead of the fuel-saving capacity of EVs in the prior period (2009-12) (Li, Yang, & Sandu, 2018).

In the second phase, in addition to the monetary incentives stated before, different non-monetary incentives were implemented. In 2015, the municipal government of Beijing exempted EVs from peak-hour traffic control and the vehicle quota system[4], aiming to curb congestion and air pollution. Furthermore, the government actively supported EV infrastructure development through financial aid for charging facilities and regulatory provisions to streamline planning (Li, Yang, & Sandu, 2018). As a result of such policy support, China witnessed a significant uptick in its EV infrastructure, culminating in nearly 1.8 million public electric vehicle charging piles by the end of 2022, a substantial 56.7 % increase from the previous year (Statista, 2024).

[4] Also known as the lottery system, this system was introduced in 2011, in order to limit the growth of vehicles on the roads, as a result of growing public concerns about traffic congestion and air pollution

Figure 3- Number of Charging Piles in China (in thousands)



Source- EVCIPA, 2023.

Phase III (2018-Present)

NEV Mandate and way ahead

China initiated the transition to a market-based zero-emissions vehicle credit system in 2018, drawing inspiration from the Zero Emission Vehicle Mandate implemented in California. China applied the lesson learned from California's predicament and postponed the implementation of targets until it attained a specific level of technological advancement and market readiness. By implementing this strategic approach, policies were optimised and given a unified, distinct purpose. Within this framework, credit objectives for New Energy Vehicles (NEVs) are set in relation to the conventional passenger vehicle market. More precisely, they are 10% for the year 2019 and 12% for the year 2020. Similar to California's ZEV mandate, annual percentages for NEV credits are established in lieu of sales. The allocation of credits to individual NEVs is contingent upon a range of performance metrics, including energy efficiency and electric range. Each vehicle is limited to a maximum of six credits, thereby enabling a market share for NEVs that is adaptable and contingent upon the fleet composition (WRI, 2018; ICCT, 2018). Compliance to these NEV credit targets is obligatory for all automotive companies that produce or import more than 30,000 conventional vehicles annually. Organisations that meet their NEV credit obligations can purchase credits to make up the difference, while those that fall short can exchange their excess credits. Additionally, any deficits in Corporate Average Fuel Consumption (CAFC) credits may be offset by excess NEV credits. This system, commonly known as the "dual credit" policy, synchronises the NEV credit scores of manufacturers with their fuel economy accomplishments. The Ministry of Industry and Information Technology (MIIT) may impose sanctions on businesses that fail to meet NEV credit targets and exhaust all compliance options. These sanctions may include a suspension of approval for new models that fail to meet specific fuel consumption standards until the companies rectify their deficits. As of now, the dual-credit policy has proven to be efficacious in stimulating the expansion of NEVs, and it is expected to be a crucial factor in China attaining its ambitious target of a 20% market share for NEVs by 2025 (Chen, 2022; ICCT, 2019).

China's current policy suite is robust and includes carmakers exemptions from consumption tax and vehicle & vessel tax for the production, processing, and importation of EVs as well as is phasing away from subsidies on certain vehicles (Jaeger, 2023). On June 21, 2023, a significant tax incentive package worth, 520 billion Yuan (USD 72.3 billion)was disclosed. This package, which spans four years, was designed to provide tax exemptions for EVs and other environmentally sustainable vehicles. This initiative provides a prospective exemption of purchase tax of RMB 30,000 (USD 4,170) per vehicle, in its entirety. From 2026 to 2027, however, this exemption will be reduced in half and limited to RMB 15,000 (approximately USD 2,078) (WRI, 2018).

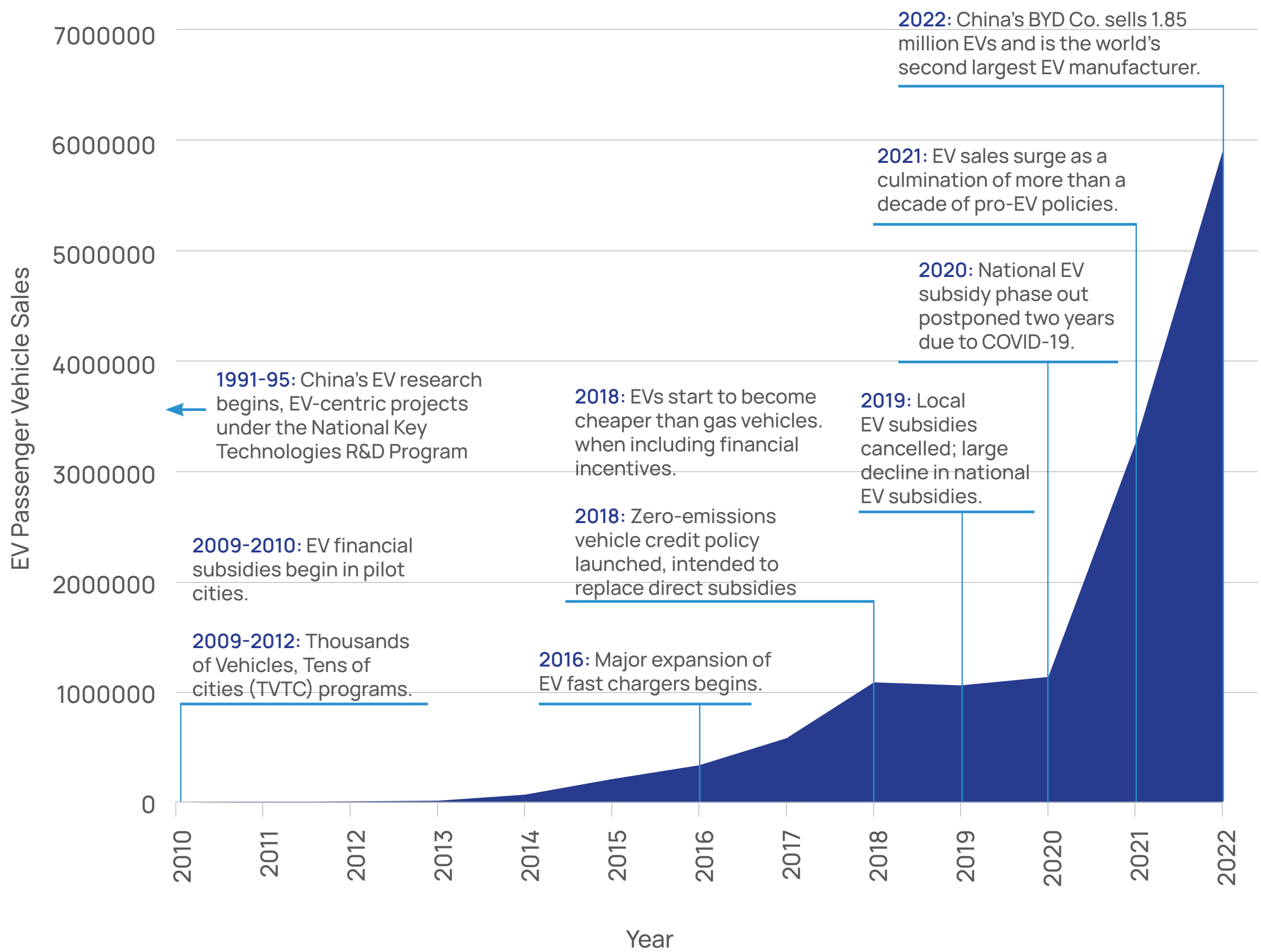
Additionally, any new EVs purchased by December 31, 2025, will be exempt from the vehicle purchase tax, with purchases between January 1, 2026, and December 31, 2027, enjoying a

50% tax

reduction.

These incentives are complemented by discounted electricity tariffs for EV charging and battery-switching facilities, along with government-regulated service fees for EV charging and switching. The grid-conversion costs for these facilities are now integrated into the tariffs for power transmission and distribution (Jaeger, 2023).

Figure 4- Evolution of Policies in China



Source - WRI, 2018; Authors' Analysis.

Although the main strategy for achieving a low-carbon transformation in many countries is the use of carbon trading mechanisms for companies and key industries, access to the carbon trading market is unfortunately primarily available to a small group of decision-makers and excludes regular households, educational institutions, small businesses, etc. China is exploring innovative approaches like personal carbon trading (PCT) to incentivize sustainable behaviours at the individual level. Although PCT presents challenges in terms of complexity and fair implementation, it holds the potential for enhancing carbon emission awareness and supporting low-income groups who typically have lower emissions (Xu, et al., 2023). In essence, China's success in the EV ecosystem can be attributed to its evolving policy landscape that adeptly combines infrastructure development, R&D incentives, fiscal policies, pioneering market-based schemes and the NEV mandate to continue driving its EV agenda forward, not only creating a cleaner environment but emerging indispensable in the EV global value chain.

2.3 European Union- Initiatives and Voluntary ZEV Targets

The European Union is at the forefront of addressing vehicle emissions with its rigorous and all-encompassing regulations. The European Union has achieved nearly negligible levels of exhaust emissions through the implementation of cutting-edge technologies (ACEA, 2023). Aligned with its climate objectives, the European Union is making strides in the direction of healthier transport, with net-zero emissions by 2045 and a 65% reduction in pollution from 1990 levels by the end of the decade (Niranjan, 2023). A significant component of this transition is the adoption of EVs, with EV registrations comprising 21.6% of all new car registrations in 2022. The increase in EVs, projected to reach 40 million by 2030 from the current 8 million, is supported by European Union initiatives that encourage electric mobility and the development of charging infrastructure. (European Environment Agency, 2024)

EV Initiatives across the European Union

Across the EU, the high upfront costs of EVs present a challenge. To mitigate this, financial incentives across EU member states have been introduced, with 21 offering tax breaks and 20 providing purchase subsidies. For instance, Romania offers up to €11,500 for EV buyers, Belgium focuses on company cars to nourish the second-hand market, and Italy and Spain invest in charging infrastructure. France promotes a €5,000 bonus and a social leasing scheme, while Germany has trimmed subsidies due to a rise in EV adoption. Additionally, two-thirds of EU states incentivize the purchase of electric commercial vehicles, with varied fiscal supports and tax benefits to boost the market (Niranjan, 2023; ACEA, 2023).

In February 2023, the European Union introduced the Green Deal Industrial Plan, which revolves around four key areas – (i) accelerating the permitting process, (ii) providing financial support, (iii) fostering the development of skills, and (iv) enhancing trade relations. Central to this initiative is the formation of a Critical Raw Materials Act, proposed in March 2023, emphasizing the security of supply chains, responsible sourcing, and the recycling of materials. (European Commission, 2023) (IEA, 2023)

Encouraging expedited approval processes for projects, with a particular emphasis on those related to battery manufacturing, is one of the primary objectives of the Net Zero Industry

Act. The purpose of this act is to predict and expedite the planning procedure. Additionally, it implements a temporary relaxation of state aid regulations in order to streamline the process of obtaining subsidies and loans. This measure is expected to assist businesses in managing exorbitant energy expenses, maintaining liquidity, and reducing electricity usage. Furthermore, the strategy incorporates actions aimed at reskilling employees who are adversely affected by the transition to an environmentally sustainable economy, including the creation of Net Zero Industry Academies. The trade component of the strategy aims to enhance the resilience of the European Union's supply chain, foster commerce with untapped partners, and attract investments from the private sector. In support of these endeavours, the European Union introduced the Net Zero Industry Act in March 2023, which establishes the objective of producing 40% of the EU's critical net-zero technologies domestically by 2030. This act places significant emphasis on the progress of battery and energy storage technologies, establishing a bold objective for the European Union to manufacture approximately 90% of its battery needs. This conforms to the objective of the European Battery Alliance, which is to attain a minimum manufacturing capacity of 550 GWh by the year 2030. Simultaneously, automobile sales will be subject to more stringent regulations from 2030 to 2035, as stipulated in the Fit for 55 legislative packages (European Commission, 2023; IEA, 2023).

To support the growing number of EVs, the Alternative Fuels Infrastructure Regulation (AFIR) plays a critical role in ensuring the stability of the EV charging environment. It sets common standards and guidelines for the EU, including provisions such as accessible fast-charging stations and transparent pricing (European Environment Agency, 2024).

EU Voluntary ZEV Targets

The European Union's approach to ZEVs differs from the mandates in California and China. Instead of imposing strict requirements, the EU offers car manufacturers the opportunity to meet voluntary ZEV quotas, which can then be used as compliance offsets against the stringent post-2021 corporate average standards. (ICCT, 2019).
In anticipation of the future, the European Commission endeavours to reduce these emissions by an additional 15% by 2025 and by 37.5% by 2030. Nevertheless, the manner in which vehicles contribute to these objectives differs: Fuel Cell Electric Vehicles (FCEVs) and Battery Electric Vehicles (BEVs) that produce no are granted complete credit towards these targets, whereas vehicles that emit between

At present, EU Regulations mandate that automobile manufacturers reduce fleet-wide emissions to

95

grammes per kilometre

on average by 2021.

0 and 50 grammes per kilometre are only partially credited. Automobiles that exceed 50 grammes per kilometre contribute nothing to the voluntary objectives (ICCT, 2019).

In order to provide manufacturers with flexibility, the European Commission has integrated these voluntary ZEV targets into the corporate average standards. By exceeding these targets, producers may be eligible for a relaxation of their regulations. To illustrate, in the event that a manufacturer attains 17% BEV sales in 2025, they shall be granted a compliance relaxation factor of 1.02. Similarly, should they achieve 39% BEV sales in 2030, the relaxation factor shall be reduced to 1.04. The incentive is structured to encourage manufacturers to surpass their ZEV targets by a maximum of 5%, with a relaxation limit of 1.05. It is crucial to note that the absence of specified penalties for non-compliance with the ZEV objectives underscores the voluntary character of the programme (ICCT, 2019).

The moratorium on new petrol and diesel vehicles in the United Kingdom (UK) has been delayed until 2035, by Prime Minister Rishi Sunak. This information is consistent with the Department for Transport's ZEV Mandate, which establishes increasing sales targets for electric vehicles until 2035. By 2035, the mandate calls for all new car sales to be emission-free, with the percentage increasing annually to 80% for cars and 70% for trailers by 2030, with an initial target of 22% in 2024. In years where manufacturers fall short, they have the option to carry over excess compliance to the following year or purchase compliance (Drive Electric, 2023; Politico, 2023).

Stricter Standards for Greener Transport

Set to take effect in July 2025, the Euro 7 Regulations will have stringent standards for vehicle exhaust and non-exhaust emissions, like those from tyre wear and brake dust, as well as enforce limits on battery life (European Council, 2024). The introduction of these rules, however, presents a double-edged sword for the European automotive industry. While they aim to facilitate the EU's green ambitions and enhance air quality, they also threaten the viability of certain vehicle models and could potentially impede the industry's progress towards a zero-emission future. This could adversely affect the EU auto industry's global standing, as they struggle to balance stringent regulations with the need to remain competitive and the growing market presence of Chinese electric vehicles. In contrast, other key global players are creating conducive environments for their transport sectors through incentives rather than strict regulations (ACEA, 2023).

It's clear that the EU has made considerable strides in its environmental efforts and has proposed numerous proactive strategies. The voluntary targets, which have so far supported manufacturers in aligning with evolving standards, illustrate the EU's commitment to a greener future. Moving forward, what Europe needs is a comprehensive and cohesive strategy that not only encourages but also materially supports significant investments in domestically produced zero-emission transport solutions. This approach will help ensure that the transition to a sustainable transport sector is both effective and economically viable (ACEA, 2023).

2.4 Norway- Remarkable Path Towards E-Mobility

Norway is an exceptional case study in the adoption of EVs, as it has the greatest proportion of EVs, accounting for 80% of passenger vehicle sales in 2022 (Jaeger, 2023). Norway's approach to the adoption of electric vehicles diverges considerably from the strategies implemented by the European Union, China, and the United States of America. Norway, instead of prioritising production, has effectively utilised consumer incentives to cultivate a demand-driven market. Norway's unique approach can be attributed, in part, to its substantial financial resources and limited manufacturing capabilities, which outweigh those of numerous developing and developed countries.

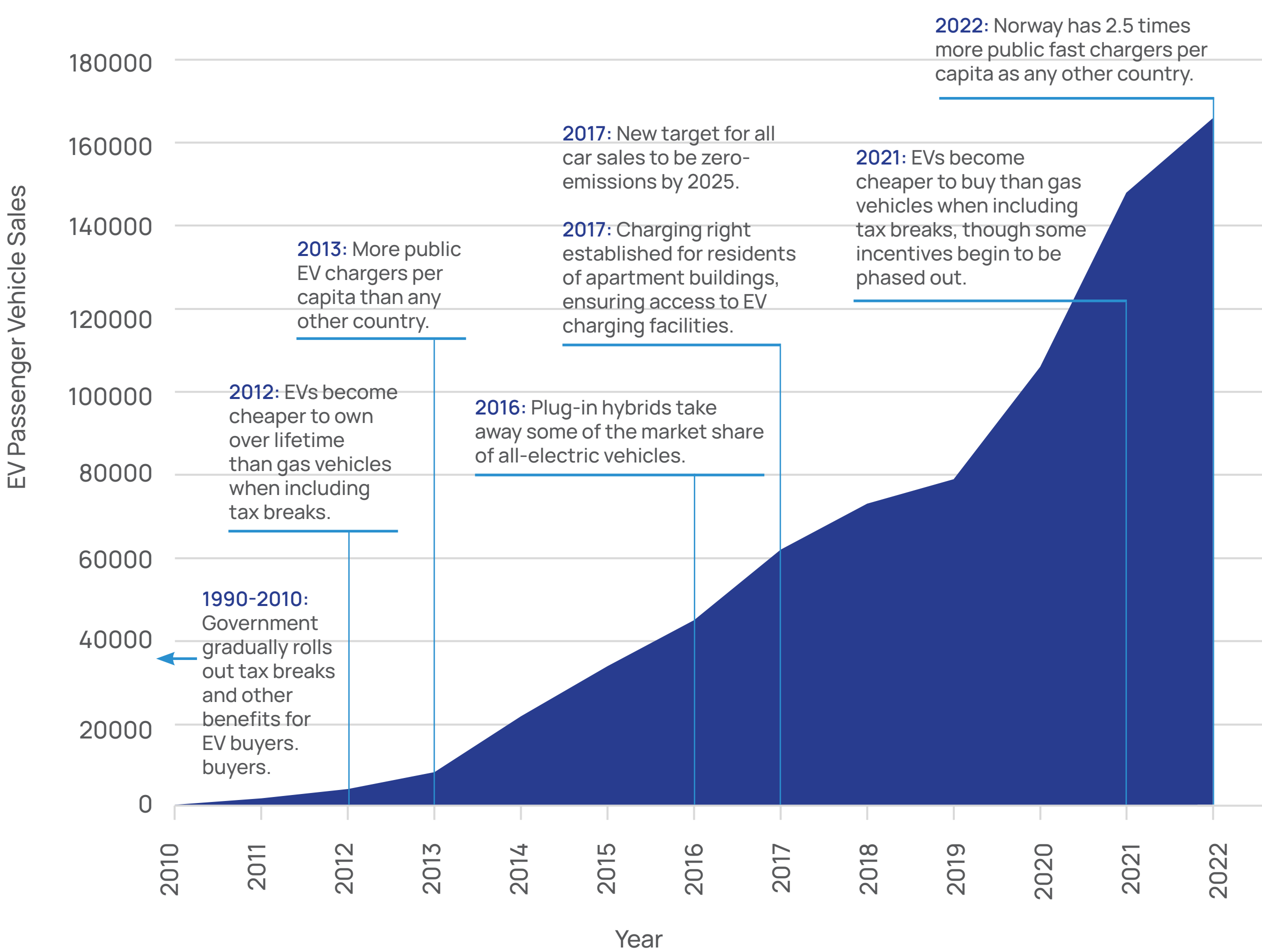
Since the 1990s, Norway has been at the forefront of implementing strategic measures to promote EVs. It started by making EVs the best financial decision for consumers supported by exempting import tax, value-added tax, road tax, toll charges, car tax, investing in charging infrastructure, and so on. These measures were introduced from the 1990s to the early 2010s by various governments with converging objectives which persist to this day in varying forms. However, Norway's journey has been far from smooth, requiring continuous revisions. Despite substantial incentives, the adoption of EVs in Norway only gained momentum as technological advancements were realized (Jaeger, 2023). The initial pace was slow, with the first 10,000 EVs taking four years to sell from 2008 to 2011. However, by 2022, the same volume of EVs was purchased within mere four weeks, signifying a rapid uptick in their acceptance (Békés , et al., 2023). A pivotal shift occurred circa 2012 when the cumulative cost of EV ownership, factoring in purchase, maintenance, and charging, fell below that of conventional gasoline or diesel vehicles, inclusive of tax incentives (Jaeger, 2023). This economic advantage catalysed a surge in the demand for charging infrastructure, hinting at the strategic benefits for investors who expand and enhance EV charging networks in anticipation of electric vehicles reaching price equivalence with internal combustion engine vehicles in their respective markets. As Norway achieved significant EV penetration, the government began to carefully recalibrate and roll back certain initiatives, aligning with its net-zero goals while maintaining a steady momentum in EV adoption. This phased and strategic approach has positioned Norway as a global leader in embracing electric mobility.

Norway's approach to the development of EVs and related policies is informed by empirical evidence gathered over the years through numerous studies and business models. EV prototype and propulsion system R&D began in the 1970s, with extensive testing running through 1999. In a significant move in 2008, the Norwegian Ministry of Transport and Communication convened a specialized group, spearheaded by Energi Norge, to formulate a comprehensive action plan aimed at the electrification of road transport. Concurrently, the government initiated the Klimakur project and conducted a thorough assessment of potential emission reductions across all sectors, with the transport sector's initiatives being directed by the Norwegian Public Roads Administration. The insights from these studies have been instrumental in the creation of policies that have paved the way for electric Mobility in Norway (Center for Public Impact, 2016).

Beginning in 1990 and extending through 2022, EVs were exempt from purchase or import taxes. This exemption was modified in 2023 to incorporate a variable purchase tax that was determined by the weight of the vehicle. A lengthy exemption from the standard 25% Value Added Tax (VAT) on purchases was established under the "Polluter Pays First" principle. However, in 2023, this exemption was restricted to vehicles worth more than 500,000 Norwegian Kroner. Additional advantages were implemented in 1999 and 2005, namely complimentary municipal parking and access to bus lanes. In 2016, regulatory modifications were made to the policy in an effort to promote carpooling among EV users. The advantages of the company car taxation policies diminished over time, beginning with a 50% reduction in the tax from 2009 to 2017, continuing to decline to 40% from 2018 to 2021, and finally reaching 20% in 2022. The incentive schedule additionally incorporates the elimination of yearly road taxes until 2021, followed by their gradual reintroduction beginning in 2022. The trajectory of ferry charges for electric vehicles was comparable. Significantly, a VAT exemption was implemented for leasing in 2015.

In 2017, the Norwegian Parliament set an ambitious national target for all new cars sold by 2025 to be zero-emission. That same year, a "charging right" was established for residents of apartment buildings, ensuring access to EV charging facilities. For longer-distance trips, a well-organised charging infrastructure has been created on all the main roads of Norway. As of 2022, more than 5,600 cars could be fast-charged at the same time (Center for Public Impact, 2016) (Norsik elbilforening, n.d.). Along with this, Norway exempts electric vehicles from import duties and registration taxes. Additionally, the country predominantly harnesses hydropower for its electricity needs, which enhances the environmental benefits of using electric cars in Norway (Richter, 2023).

Figure 5- Evolution of Policies in Norway.



Source - WRI, 2018; Authors' Analysis.

In the year 2021, Norway witnessed an impressive trend where electric vehicles constituted approximately two-thirds of the new passenger vehicle market (OECD, 2022). Projected figures from the government suggest a potential surge in the ZEV stock to 1.25 million by the year 2030, a significant increase from the 225,000 estimated in the absence of incentives (Békés , et al., 2023). These fiscal incentives have proven pivotal in catalysing the shift in consumer demand towards ZEVs, thereby expanding their prevalence within the national vehicle fleet. The Norwegian government is currently channelling efforts into the creation of a sustainable vehicle taxation framework, reflecting the triumph of electric mobility. The acceleration of the ZEV transition has been further facilitated by public investments aimed at the establishment of an extensive network of charging stations. This includes the strategic implementation of cost-effective batteries and related services.

By 2020, Norway's Infrastructure boasted in excess of

13,000

charging stations, with close to

1,600

designated as high-speed charging points, funded through public subsidies.

Complementing these developments, Enova, a state-operated entity, has contributed to the enhancement of charging facilities for approximately 150 city buses in Oslo (Békés , et al., 2023).

Although successful in encouraging the adoption of ZEVs, the fiscal consequences of the incentive programme in Norway are not inconsequential. The revenue generated from car-related excise duties has experienced a substantial decline. In 2021, the value-added tax exemption on ZEVs resulted in a loss of 11.3 billion Norwegian Kroner (equivalent to approximately USD 1.3 billion). In contrast, the economic advantage of electric vehicles, encompassing both completely battery electric and plug-in hybrid models, was computed to be 30 billion Norwegian Kroner (approximately USD 3.5 billion) during the aforementioned year. Although the sales of ZEVs have increased as a result of these policy-driven incentives, tax revenues, which account for nearly one-third of the nation's environmental tax revenues, have decreased as a consequence. Therefore,

in a paradoxical turn of events, the efficacy of these fiscal instruments has backfired on them, as the reduction of environmentally harmful activities has undermined the tax base (Békés, et al., 2023). As a result of these circumstances, the government is considering implementing a value-added tax (VAT) on electric vehicles of higher trim levels. This would be an initial effort to reallocate the financial burdens associated with road maintenance, infrastructure development, and other externalities of a similar nature. In addition, the implementation of a time- and location-adjusted road use tax is suggested as an acceptable measure, indicating a transition towards a more sustainable and balanced fiscal approach.

The competitive landscape of Norway's Electric Vehicle Charge Infrastructure (EVCI) market has remained robust, driven by a high level of demand. Despite this demand, the industry has yet to see a definitive market leader emerge, as initial efforts have predominantly catered to the early adopters. Currently, as the market expands and consumer expectations grow more complex, the competitive atmosphere is becoming more acute. Operators are now under increasing pressure to provide superior services. This trend is anticipated to replicate itself globally as EV adoption rates increase, technologies advance, and consumer demands evolve. (Békés , et al., 2023)

Clearly, Norway has achieved success in establishing an ecosystem that prioritises electric mobility as the most expedient option for consumers. Nevertheless, in order to fully appreciate the progress achieved by Norway, it is essential to place its economic environment in context. Norway's capacity to designate significant subsidies towards EVs is paradoxical, considering that the country's prosperity is predominantly derived from its vast oil reserves. This characteristic sets Norway apart from other nations and implies that attempting to emulate its model would be impracticable for countries that possess distinct political and economic frameworks. In light of this, it is critical, when contemplating the widespread implementation of such systems, to evaluate the approaches taken by other economies that have successfully transitioned to electric mobility under diverse circumstances.

2.5 Takeaways from the Implementation of ZEV in Economies

An examination of the ZEV policies across these nations reveals a set of common strategies that have been instrumental in sculpting the landscape for electric vehicles, making the ZEV mandate effective within their respective domains. These strategies have matured over time, mitigating challenges, and evolving into robust policy frameworks.

Table 2- Key Insights from ZEV Implementation in Economies leading EV transition.

Country	Key Takeaways from ZEV Implementation
United States	Incrementally Increasing Stringent Credit Requirements
	Differentiation Among Manufacturers based on manufacturing capacity
	Long-term Vision of product standards with Sales Compositions
	Monetary Benefits for low Income Consumers
	Emphasis on Long term Fuel savings
	Funding for Infrastructure Expansion
	Legislative Support
China	Strategic Policy Implementation after attaining level of Technological development
	Credit-Based System in the basis of efficiency of vehicle produced
	Mandatory Credit Targets with Trading Option
	Dual-Credit Policy to address fuel efficiency and promote NEVs
	Penalties for Non-Compliance
	Tax incentives and Breaks
	Supportive Infrastructure policies
European Union	Flexibility in Compliance
	Incremental Emission Reduction Goals
	Differential Credits for different types of EVs.
	Relaxation of emission standards on the basis of sales targets
	Rolling Over Compliance:
	Long-Term Vision with Escalating Targets
Norway	Long-Term Tax Exemptions
	Incremental Policy Adjustments
	Making EVs the best choice for consumers through economic advantage
	Charging Infrastructure Investment
	Legislative Support for Charging
	Gradual Introduction of Taxes
	Strategic Financial Planning

Source - WRI, 2018; Authors' Analysis.

By analysing these key takeaways and integrating them within the Indian context, the nation can enhance its existing environmental landscape, thereby laying a solid foundation for the potential implementation of a ZEV mandate.

03

India's Automobile Sector: Current Landscape

In order to conduct a thorough assessment of the effects of the ZEV mandate in India, it is imperative to commence by gaining an understanding of the present state of the Indian automotive industry. This includes an analysis of the company's sales, production, and value chain elements, as well as the ongoing transition to electric mobility. A comprehensive examination of these industry components will serve as the basis for evaluating the prospective impact of the ZEV mandate.

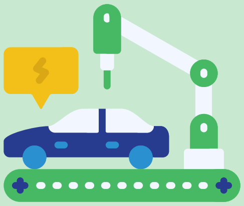
Presently, there is a noticeable imbalance between component manufacturers and Original Equipment Manufacturers (OEMs), with the industry being heavily reliant on demand-side incentives. While production capacity is gradually increasing, the transition to electric vehicles is predominantly being driven by a select few OEMs. The introduction of stringent regulations, coupled with mandatory compliance and associated penalties, has the potential to streamline these efforts and bridge the disparities within the sector. Therefore, a thorough examination of the current state of the automobile industry, its policies, and its value chain is imperative to grasp the significance of the ZEV initiative and its prospective impact upon implementation.

3.1 Indian Automobile Sector

The efficiency of any policy in an economy depends on the current standing and the ecosystem of the industry. The Indian Automobile Industry has held an integral spot in the Indian economy. India achieved the status of becoming the third-biggest vehicle market in December 2022 (Ministry of Finance, 2023).

The industry has had significant growth, increasing from 2.77% in 1992-93 to 7.1% throughout the years (PIB, 2023; Ministry of Finance, 2023).

The value of India's Automotive market in 2021 was USD 100 Billion and is projected to reach



USD 160 Billion by 2027,

with an annualized growth rate (CAGR) of 8.1% over the forecast period 2022-2027 (Mordor Intelligence, 2023).

In 2021, it accounted for 49% of the manufacturing GDP and produced a total of 3.7 crore direct and indirect jobs (Ministry of Finance, 2023).

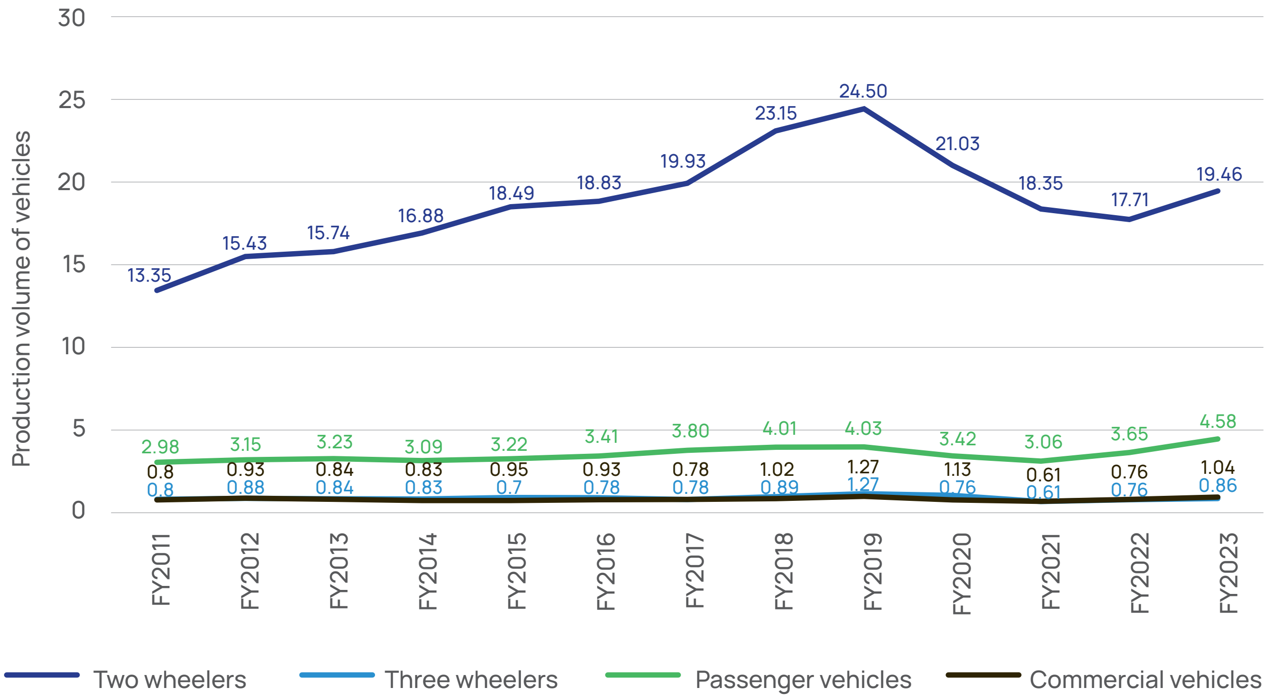
From April 2000 to March 2023, the industry received a total of USD 34.74 billion in foreign direct investment (FDI), which accounted for 5.45% of the total FDI in equities during this period (IBEF, 2024).

India occupies a major place in the global heavy vehicles industry, being the largest producer of tractors and two-wheelers, the second-largest producer of buses, and the third-largest producer of heavy trucks worldwide (PIB, 2023; Invest India, 2023).

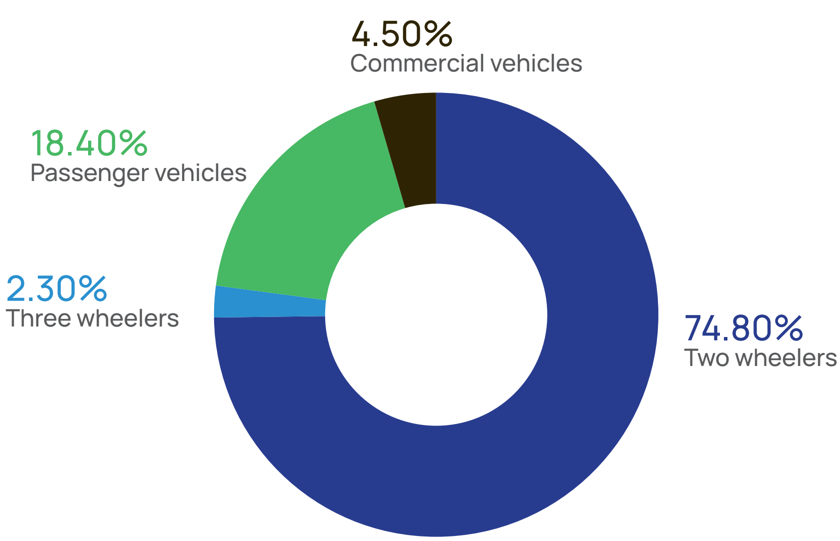
In the fiscal year 2022-23, the industry manufactured a total of 2,59,31,867 vehicles, comprising passenger vehicles, commercial vehicles, three-wheelers, two-wheelers, and quadricycles, signifying significant growth compared to the previous year's output of 2,30,40,066 units. Within this period, two-wheelers dominated the market with a substantial 74.8% share, while passenger cars constituted 18.4% (SIAM, 2022).

Figure 6- Overview of Indian Automobile Industry Production and Components.

Production volume of vehicles across India from financial year 2011 to 2023, by segment (in millions)



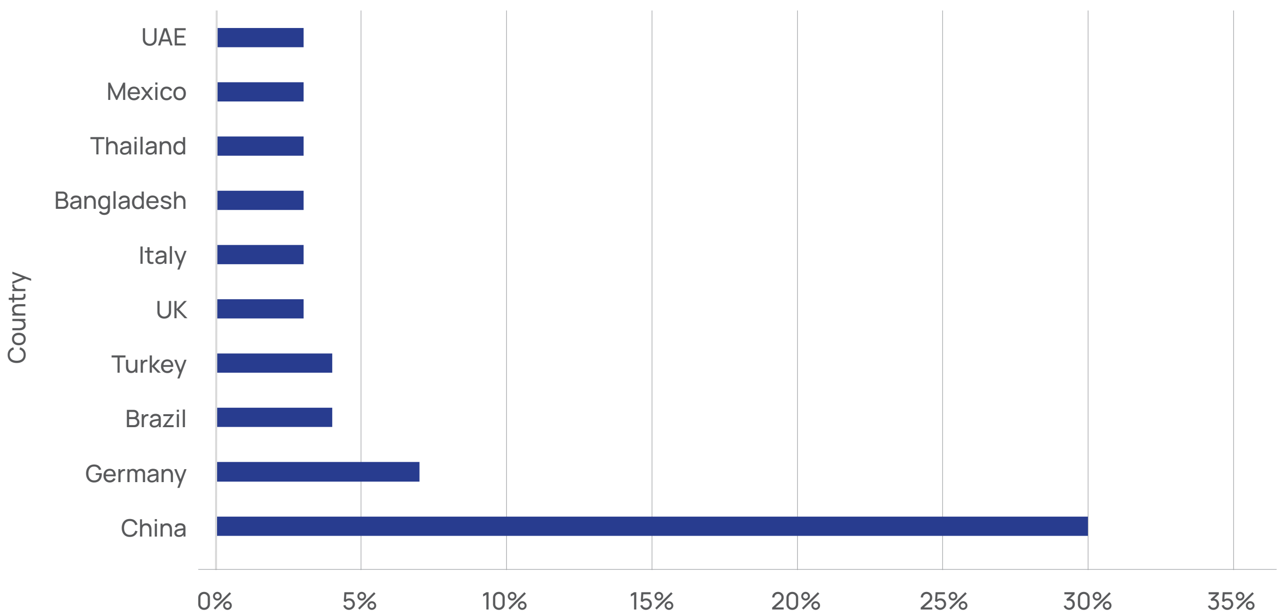
Share of each Segment in Total Production Volume (FY23)



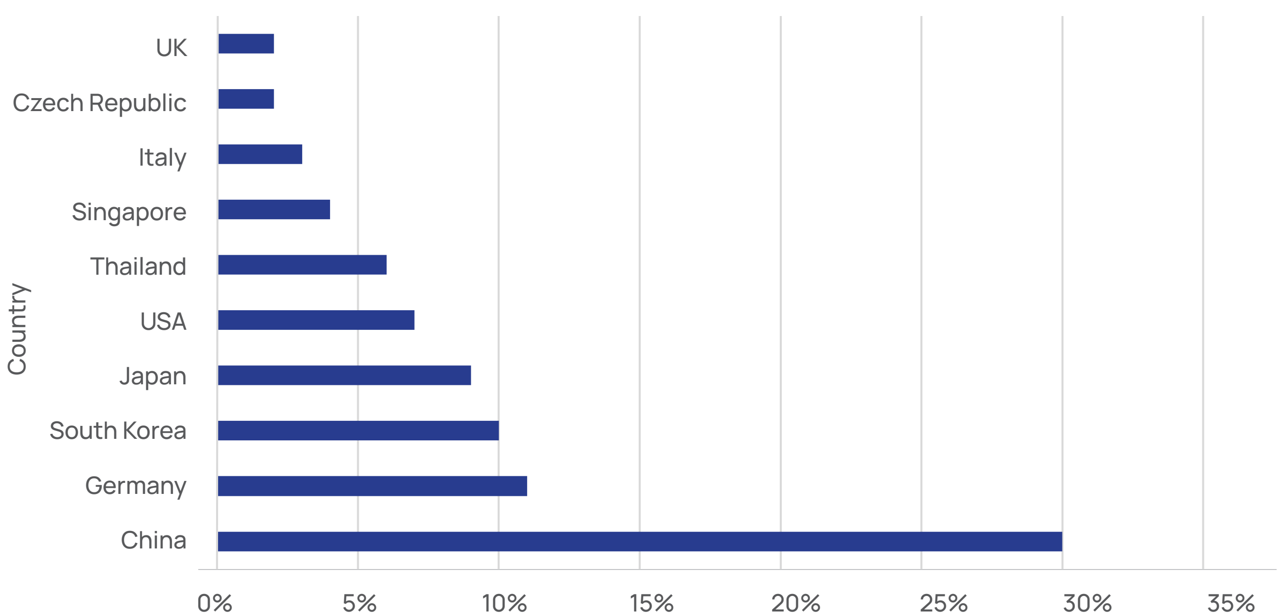
Source- SIAM, 2023

Figure 7- Leading Sources and Destinations of EV Components

Exports (% of total)



Exports (% of total)



Source- ACMA, 2023

The auto components industry adds

2.3%

to India's GDP and provides direct employment to 1.5 million people.

During the period from FY16 to FY22, despite a CAGR of 6.35% to a value of USD 56.50 billion, the sector has a heavy reliance on imports, particularly for auto-electronics, which comprises 64% of the demand (ACMA, Grant Thornton, 2023).

A trade deficit of USD 20 million in FY 2023 highlights a modest export growth of 5% against an 11% surge in imports, reflecting the nascent stage of EV manufacturing in India. The export trajectory of auto components is anticipated to expand, targeting a figure of USD 30 billion by the fiscal year 2026 (IBEF, 2023). This growth in imports can be primarily attributed to the increasing prominence of EVs and the embryonic stage of EV manufacturing within India. An examination on a country-wise basis indicates that the United States stands as the principal destination for exports, whereas China emerges as the primary source of imports (ACMA, 2023).

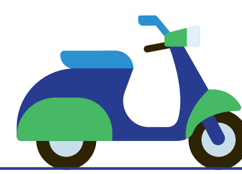
3.2 A Shift in the Indian Automobile Industry with the Rise of Electric Vehicles

Prime Minister Narendra Modi outlined the vision for the future of mobility in India during the 2018 Global Mobility Summit in New Delhi, emphasizing seven key principles – Common, Connected, Convenient, Congestion-free, Charged, Clean, and Cutting-edge (PIB, 2018). Aligning with this vision, Amitabh Kant, G20 Sherpa of India, stressed the importance of transitioning 100% of 2-wheelers and 3-wheelers, and 65%-70% of buses to EVs by 2030 to meet the EV30@30 targets. According to a CEEW study (Soman, Kaur, Jain, & Ganesan, 2020) achieving 30% EV sales could result in a 31% reduction in oil imports, generate approximately 121,422 jobs in the EV value chain, create a market opportunity exceeding INR 2 lakh crore (USD 26 billion) for EV powertrain and batteries, and about INR 13,372 crore (USD 1.8 billion) for public charging infrastructure by 2030.

Currently, two-wheeler (2W) EVs form the majority of EV sales today, accounting for

85%–90%

of all EV units sold in India,



followed by four-wheeler (4W) EVs (7%–9% of sales) and three-wheeler (3W) EVs (5%–7% of sales) (Seetharaman, et al., 2023). Penetration of EVs by 3Ws is 8%, followed by e-buses at 7%, e-2Ws at 5%, and passenger vehicles hovering around 1%. By 2023, e-rickshaws, constituting 90% of the 3 Wheelers, achieved

a penetration rate of 53%, driven by factors such as accessibility, low maintenance costs, advancing technologies, and the growing demand for efficient passenger transportation (Vahan Dashboard, 2023) (Economic Times, 2023).

Currently, two-wheeler (2W) EVs form the majority of EV sales today, accounting for 85%–90% of all EV units sold in India (Seetharaman, et al., 2023). The proliferation of two-wheeler and three-wheeler vehicles has been significantly propelled by a milieu of innovation and supportive activities, such as retrofitting and the implementation of Battery-as-a-Service (BaaS) models. For instance, Sun Mobility, India's prominent BaaS provider, provides BaaS models for last-mile services of 2Ws and 3Ws. Sun Mobility has partnered with various delivery firms like Swiggy and EV manufacturers like Bouncy Infinity to increase the proliferation of electric two-wheelers through BaaS. The high pace of innovation and adaptation especially among dedicated EV manufacturers, is largely attributed to the enactment of progressive policies, alongside the deployment of FAME I and II subsidies. These factors coupled with a vast market have made it profitable for purely EV manufacturers to enter the market (Currently various pure two-wheeler EV manufacturers like Ather, Ola, and Bouncy Infinity are prominent in the market). The coexistence of pure EV manufacturers and manufacturers producing both ICE and EV has ensured a consistent supply of evolving products catering to an expanding consumer base.

The three-wheeler market has also witnessed substantial penetration of EVs, primarily led by e-rickshaws, which constitute 90% of this segment.

As of 2023, the penetration rate for e-rickshaws reached an impressive 53% contributing significantly to the overall 8% penetration of EVs in the three-wheeler market.

This notable adoption can be attributed to factors such as heightened accessibility, cost-effectiveness in maintenance, continuous technological advancements, and a rising demand for efficient passenger transportation (Vahan Dashboard, 2023) (Economic Times, 2023).

However, the four-wheeler automotive segment remains in a nascent phase, characterised by a significant sensitivity to price and accounting for a mere 1% of market penetration despite accounting for 7%–9% of sales. A technological capacity bolstering and an influx of technological innovation are crucial for this market segment. At this time, the sector relies heavily on imported batteries, which indicates a lack of domestic innovation, specifically concerning powertrain development, battery technology, and the training of a proficient labour force. The implementation of focused policy reforms to stimulate progress in these areas is critical in order to take advantage of the expanding four-wheeler market and enhance adherence to global benchmarks.

3.3 Government Initiatives Driving the Shift to Electric Mobility

India is embracing e-mobility as a global solution to enhance sustainability and efficiency in the transportation sector. The country has implemented a series of policies to guide the industry's trajectory, addressing technological advancements, infrastructure, regulatory frameworks, and incentives. These policies aim to create a synergistic ecosystem for India's transition to E-mobility. The success of these policies depends on the active engagement of all stakeholders, including manufacturers, consumers, and government bodies. Collaborative efforts among these stakeholders ensure a comprehensive understanding of challenges and opportunities. The establishment of these policies marks a significant step in shaping India's future, positioning it as a global player in sustainable and efficient transportation. The success of these policies depends on continued collaboration and adaptability, paving the way for a robust and dynamic e-mobility ecosystem.

Central Policies

Central policies in India shape the EV industry by providing a structured framework, promoting technological innovation, sustainable practices, and seamless integration. They act as catalysts, aligning industry goals with national objectives, and contributing to India's sustainable and energy-efficient transportation future by fostering an environment conducive to EV growth and adoption. The following table and flow chart comprehensively illustrate the timeline and objectives of various central policies in the EV Automobile industry.

Figure 8- Evolution of EV policies in India.

2002

National Auto Policy
was one of the first polices focused on increasing value addition and modernising the sector

2003

National Electric Mobility Mission Plan
Launched by the GoI in 2013, the NEMMP, endorses hybrid and electric vehicles with a target of six to seven million units by 2020

2005

Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
Phase I introduced on April 15 to reduce the purchasing price of hybrid and electric vehicles

Fuel consumption standards
aim to increase fuel efficiency of vehicles road by 35% by 2030. Introduced in two target phases: Carbon dioxide emission target of 130 gram/kilometre by 2022-23 and 113 g/km 2022-23 onwards

2021

Production Linked Scheme (PLI) for Automotive sector and Advanced Chemistry Cell
were approved in 2021. The PLI Advanced Automotive Technology has budgetary outlay of Rs. 25,938 crores to and PLI ACC has budgetary outlay of Rs 18000 crores

Voluntary Vehicle-Fleet Modernization Program
was announced and is aimed at creating an eco-system for phasing out of unfit and polluting vehicles.

2024

Extension of the PLI Scheme for manufacturing of ACC on January 1, 2024 with a budgetary outlay of Rs. 18,100 crore

2017

Karnataka set a precedent by introducing a state EV policy in 2017.

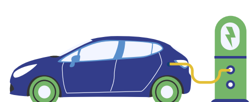
Green Urban Transport Scheme (GUTS), 2017
launched to combat air pollution in urban cities and aims to replace public transport vehicles with eco- friendly vehicles

CAFE Regulations
First implemented in India on 1st April, 2017 with the introduction of BS4 exhaust emission norms, CAFE norms. allow for super credits. Carmakers can get credits for selling relatively cleaner vehicles.

2018

NAP, 2018
Set out to gradually align India's automotive standards with those of the WP-29, it envisions the implementation of CAFE standards through 2025 and beyond. It also calls for the alignment of Automobile Industry Standards (AIS) with the dards Bureau of Indian Standards (BIS), and expedition of the Bharat New Vehicle Safety Assessment Program.

Maharashtra and Andhra Pradesh introduced respective state EV policies.



2019

FAME II
introduced in April 2019.

National Automotive Testing and R&D Infrastructure Project (NATRIP)
is a fully GoI-funded project with a total project cost of Rs. 3727.30 crore. It aims at setting up of six state- of-the-art automotive testing and R&D centres to create core global competencies and enhance competitive skills.

2020

GST on EVs has been kept in the lower bracket of 5% as against the 28% GST rate with cess up to 22% for conventional vehicles.

Source - Ministry of Heavy Industries and Public Enterprises, 2018; ACMA, Grant Thornton, 2023; PIB, 2019; PIB, 2022; PIB, 2024; National Automotive Testing and R&D Infrastructure Project, 2019; GOI, n.d.; Ministry of Road Transport and Highways, 2023; Ministry of Heavy Industries, n, d.

Table 3- Details of EV Policies in India

Policy	Timeline	Objective
National Auto Policy	2002 onwards	Increasing value addition and modernising the sector
National Electric Mobility Mission Plan (NEMMP) 2020	2013-2020	Bolstering national fuel security through the endorsement of hybrid and electric vehicles with six to seven million units for hybrid and electric vehicles, commencing from the year 2020 onwards
CAFE Norms	2014 onwards	First announced in 2014, implemented 1st April 2017 with the introduction of BS4 exhaust emission norms. Car manufacturers were obliged to meet a base target of 130gm of /km, based on an average industry kerb weight of 1,037kg.
Under NEMMP – FAME I and II	2015-2024	Increasing adoption by offering immediate price reductions, funding select pilot projects, and investing in research and development as well as public charging facilities
Green Urban Transport Scheme (GUTS)	2017 onwards	Aims to replace public transport vehicles by eco-friendly vehicles
National Auto Policy	2018 onwards	Implementation of Corporate Average Fuel Economy (CAFE) standards through 2025 and beyond, supplemented by a system of incentives and penalties, gradually align India's automotive standards with those of the World Forum for Harmonization of Vehicle Regulations (WP-29) within the next five years, promoting R&D activities and vocational training
National Automotive Testing and R&D Infrastructure Project (NATRIP)	2019 onwards	Fully Government of India funded project with a total project cost of Rs. 3727.30 crore. Aims at setting up of six state-of-the-art automotive testing and R&D centres to create core global competencies, enhance competitive skills, integrate India's IT capabilities with automotive sector

Policy	Timeline	Objective
PLI Advanced Automotive Technology products	2021-2024	Budgetary outlay of Rs. 25,938 crores to support domestic manufacturing of vehicles (including EVs) and boost manufacturing of Advanced Automotive Technology products
PLI Advanced Chemistry Cell	2021 onwards	Budgetary outlay of Rs. 18,100 crores, envisages to establish a competitive ACC battery manufacturing set up in the country for 50 GWh
Revision of CAFE norms	2022	In the second phase, from 2022-2023 onwards, manufacturers must comply with a base industry figure of 113gm of /km, based on an average industry kerb weight of 1,145kg - a reduction in output of about 13 % over the earlier period, despite the increase in weight. CAFE norms allow for super credits[5]. Carmakers can get credits by selling relatively cleaner vehicles[6].
Voluntary Vehicle-Fleet Modernization Program (VVMP)	2023 onwards	Aimed at creating an eco-system for phasing out of unfit and polluting vehicles. The program intends to make the Indian scrappage industry organised, transparent, and environmentally friendly and extract value addition from scrappage

Source- Ministry of Heavy Industries and Public Enterprises, 2018; ACMA, Grant Thornton, 2023; PIB, 2019; PIB, 2022; PIB, 2024; National Automotive Testing and R&D Infrastructure Project, 2019; GOI, n.d.; Ministry of Road Transport and Highways, 2023; Ministry of Heavy Industries, n.d.

The aforementioned central policies collectively strive to encompass the entire sector, with the goal of establishing a supportive ecosystem conducive to the transition of the automotive industry.

[5] The rules regarding super credits in the Corporate Average Fuel Economy (CAFE) standards lack clear details. There is no information in the public domain on the minimum requirements for earning super credits, their benefits, or whether manufacturers can carry over any unused credits to the next period.

[6] This is done by adopting battery electric vehicles (BEV), plug-in hybrids (PHEV) and hybrid electric vehicles (HEV). The credits are awarded as follows: 3 for BEV, 2.5 for PHEV, and 2 for HEV. Currently, there are no penalties for non-compliance to CAFÉ Such norms have nudged manufacturers to increase fuel efficiency in their current fleet and produce EVs.

Table 4- State Targets for Public Transport

State	Targets
Andhra Pradesh	11,000 state buses and 100% government fleet converted to EVs by 2024
Kerela	6000+ buses transition to EVs by 2025. After procurement of around 163 e-buses, this initiative is currently halted as Kerala conducting profit and loss study due to concerns that the electric buses in Kerala are operating at a financial loss.
Karnataka	Convert all 35000 buses into e-buses by 2030
Delhi	50% of all stage carriage buses to be EVs starting with 1000 EVs by 2020
Maharashtra	Convert 15% state buses to Electric, achieve 25% electrification of public transport in 6 major urban cities by 2025. (Mumbai, Pune and Navi Mumbai represent 42% of the total electric buses operating in India)
Tamil Nadu	Replace 5% of buses with EVs and introduces 1000 buses annually. Tamil Nadu State Transportation Department collaborates with German Based bank KfW for this target.
Uttar Pradesh	Procure 5000 EV buses in 2024-25 on a contractual basis and identify 10 EV cities with green routes and achieve 70% of EV public transportation by 2024.

Source- (IBEF, 2022) (Rawat, 2024) (The Hindu, 2024) (The Economic Times, 2022) (The Hindu, 2024) (Dhole & Gode, 2022)

These initiatives, though slowly are providing the necessary push to the states. Based on the number of e-buses sold in 2021, Maharashtra leads with 552 units, followed by Gujarat (216 units), Uttar Pradesh (192 units), Delhi (31 units), Karnataka (27 units), Bihar (26 units), and others (127 units) (IBEF, 2022). Along with government initiatives, private stakeholders have shown active interest. This year, several players such as Tata Motors, Ashok Leyland, BYD and JBM Group have shown eagerness to launch electric buses for battery-powered public transport in India (Naik, 2020).

Improving the penetration of electric buses in India necessitates a comprehensive understanding of the EV transport ecosystem and the various stakeholders involved. This ecosystem is intricate, encompassing the manufacturing of cells, battery packs, vehicle bodies, transit systems, charging stations, and maintenance depots (Patel). The adoption of electric buses faces challenges at multiple levels. Financially, rigid commercial practices and a fragmented market with limited vehicle models and suppliers hinder widespread adoption. Infrastructure-wise, obstacles include the scarcity of charging stations, complex maintenance procedures, inconsistent power supply, and a lack of support centres, leading to high downtime and reduced operational reliability. Technological barriers stem from low awareness, knowledge gaps, and performance uncertainties, exacerbated by design flaws that compromise functionality, safety, and efficiency. Additionally, the absence of specialized tools, spare parts, and repair workshops further complicates the expansion of electric bus usage. On the policy front, India struggles with the lack of a comprehensive policy framework, affecting incentives such as subsidies and tax exemptions, which are crucial for fostering the nascent electric bus industry. Battery technology and charging infrastructure are pivotal in the transition to EV public transport. Given the critical role of buses in India's public transport system, it is essential for batteries to have high endurance, enabling them to cover distances of 400 to 500 kilometers. To support these long-range journeys, the development of charging infrastructure on highways and connecting roads, equipped with technology that enables fast charging, is imperative.

State-level Policies

Transportation policy in India hinges on a cooperative model between the central and state governments, with states playing a pivotal role in managing policies tailored to local needs, including vehicle and fuel taxes and public transportation. This decentralized approach recognizes the diverse needs of the population across the country, empowering states to formulate and execute policies tailored to their local population (Ramji & Kankaria, 2022).

The PLI schemes and the FAME I and II initiatives are notable for being pioneering schemes in India that have been at the forefront of the EV revolution. These initiatives offer essential financial backing to manufacturers in the form of facility establishment subsidies and tax incentives, which aid consumers in the acquisition of electric vehicles.

At present,

33

states and UTs have policies focusing on EVs, which significantly contributes to the promotion of EV adoption and the encouragement of innovation (PHDCCI, 2024).

With the introduction of a state EV policy in 2017, Karnataka established a precedence that was swiftly followed by Maharashtra and Andhra Pradesh in 2018. It is worth noting that while all vehicle categories are covered, comprehensive EV objectives have only been established in Odisha and Assam. On the other hand, Bihar has limited its objectives to electric three-wheeler vehicles. Among the states that have implemented distinct EV policies, Haryana, Tamil Nadu, and Kerala, have deficiencies in their targets pertaining to specific vehicle segments. For instance, Haryana lacks two-wheelers and passenger vehicles, while Tamil Nadu only aims to produce passenger vehicles

and light commercial vehicles (LCVs). Likewise, Madhya Pradesh is devoid of LCV targets. Delhi, however, is actively advancing the electrification of its last-mile delivery and city logistics fleets, positioning it to potentially surpass the national objective of 20% electrification for LCVs by 2030. If other states adopt Delhi's proactive approach, this ambitious electrification rate could become a nationwide achievement (Ramji & Kankaria, 2022).

Along with this, 11 states have either waived or subsidized road tax, contributing to a more favourable environment for EV ownership. Several states, such as Maharashtra, Uttar Pradesh, Telangana, Punjab, Madhya Pradesh, and Delhi, are proactively taking steps to establish charging infrastructure. Additionally, Assam, Chandigarh, and Telangana provide a retrofitting subsidy of 15% up to INR 15,000. Across India, 21 states have electricity subsidies, with Tamil Nadu offering a notable 100% exemption on electricity tax. Further, states like Punjab, Madhya Pradesh, and Delhi incentivize vehicle scrapping and battery recycling, emphasizing a comprehensive approach to sustainable EV practices at both state and central levels (Times of India, 2023). A 2023 study (Climate Trends, 2023) assessed EV policies on 21 parameters that cover targets, allocations, demand- and supply-side incentives. reveal that only five states (Maharashtra, Haryana, Delhi, Uttar Pradesh and Punjab) have comprehensive strategies. Others show a lopsided focus, impacting balanced stakeholder engagement. Despite setting EV targets, many states are falling short, with achievements ranging from 3%-10% of their goals.

It is evident that establishing targets alone is insufficient; it is imperative to couple targets with incentives that embrace a comprehensive and holistic perspective of the entire ecosystem. Achieving this requires a clear understanding of the existing value chain, pinpointing specific areas within the value chain that wield substantial influence on the desired objectives, identifying policy gaps, and incorporating best practices from other nations into our economic framework, tailoring these practices to suit our unique political and economic climate.

04

Examining India's Automotive Value Chain

Before embarking on the adoption or evaluation of new policies and initiatives, such as the ZEV mandate, it is critical to conduct a thorough examination of the industry's ecosystem and value chain. The successful implementation of these initiatives is contingent upon their alignment with the existing value chain, ensuring they do not lead to adverse disruptions.

Therefore, it is crucial to undertake a detailed assessment of the value chain of the Indian automobile industry. This targeted analysis is specifically aimed at comprehending the structural changes that the industry is facing as it transitions towards EVs.

4.1 Value Chain Analysis

Value chain analysis developed by Michael Porter, has been used across the globe for disaggregating companies, sectors, and industries to identify their sources of competitive advantage through analysing the activities involved in delivering value to customers (Harvard Business School, n.d.). A comprehensive value chain, depicted in Figure 9 is developed based on the core principles of this concept by Michael Porter. Inferences are drawn from notable studies examining the value chain of the automobile industry (Soman, Kaur, Jain, & Ganesan, 2020; Kupper, Kuhlmann, Tominaga, Aakash, & Schageter, 2020). This visual representation illustrates the current activities within the value chain, with a predominance of internal combustion engine (ICE) vehicles and highlights the anticipated changes as India progresses in developing its automobile ecosystem to accommodate EVs.

Figure 9- Indian Automobile Sector Value Chain

SUPPORTING ACTIVITIES

FIRM INFRASTRUCTURE
(Finances and Investors)

- Banks
- Non-banking companies
- Capital markets
- Investors
- Auto-finance companies
- Insurance companies

HUMAN RESOURCE MANAGEMENT

- Human resource for vehicle (ICE) assembly, repair, maintenance.
- Skilling for battery assembly, swapping, repair and maintenance.
- Skilling for change chassis process assembly
- Skilling for charging infrastructure

TECHNOLOGY DEVELOPMENT

- Product design
- Product testing
- Innovation and research (market & material)
- Digital Technology
- Telematics
- Charging infrastructure

PRIMARY ACTIVITIES

INBOUND LOGISTICS

- Raw Material Mining
- Battery cell procurement/ manufacturing
- Other raw material procurement (eg, electrical components, telematic components, paints, metals, petroleum-based products, etc.)

OPERATIONS

A) Component manufacturing
- Drive transmission
- Engine parts (machining & assembly)
- Electrical & non-electrical parts
- Battery pack
- Motor assembly
- Electrical motor assembly

B) Vehicle manufacturing
- ICE, Hybrids, EVS

C) Manufacturing for services
- Power electronics manufacturing
- EVSE manufacturing

OUTBOUND LOGISTICS AND MARKETING & SALES

- Vehicle inspection
- Distribution networks
- Inventory Management
- Dealership
- Product positioning & branding
- Advertising and Promotion
- Sales

AFTER SALES SERVICES

- Maintenance & Service providers
- Aftermarket component
- Warranty Programs & technical support
- Battery Swap
- Battery & second life.
- Charging infrastructure providers

IMPORTANT STAKE HOLDERS

Customers

- Personal mobility
- Government fleet
- Corporate fleet
- Last mile fleet
- Cab aggregators.
- Public transport

Government & Regulatory Bodies

NITI Aayog, SIAM, ACMA, MORTH, MOHI&PE, ARAI, MoF, MEITY, State Governments

Blue- severely impacted due to EV transition
Green- additions to VC due to EV transition

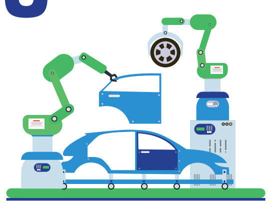
Source- Authors' Analysis based on ProwessIQ Data Base.

An examination of current companies in India, utilizing data from ProwessIQ[7], portrays the proportions of various stakeholders within the automobile ecosystem and their value addition. This includes manufacturers of automobiles, automobile components, electrical and non-electrical machinery, mineral fuel-based products, chemical and chemical products, as well as non-financial services such as trade and commission services, and research and development. (Refer to Section 1 of the Appendix).

The data shows that the majority

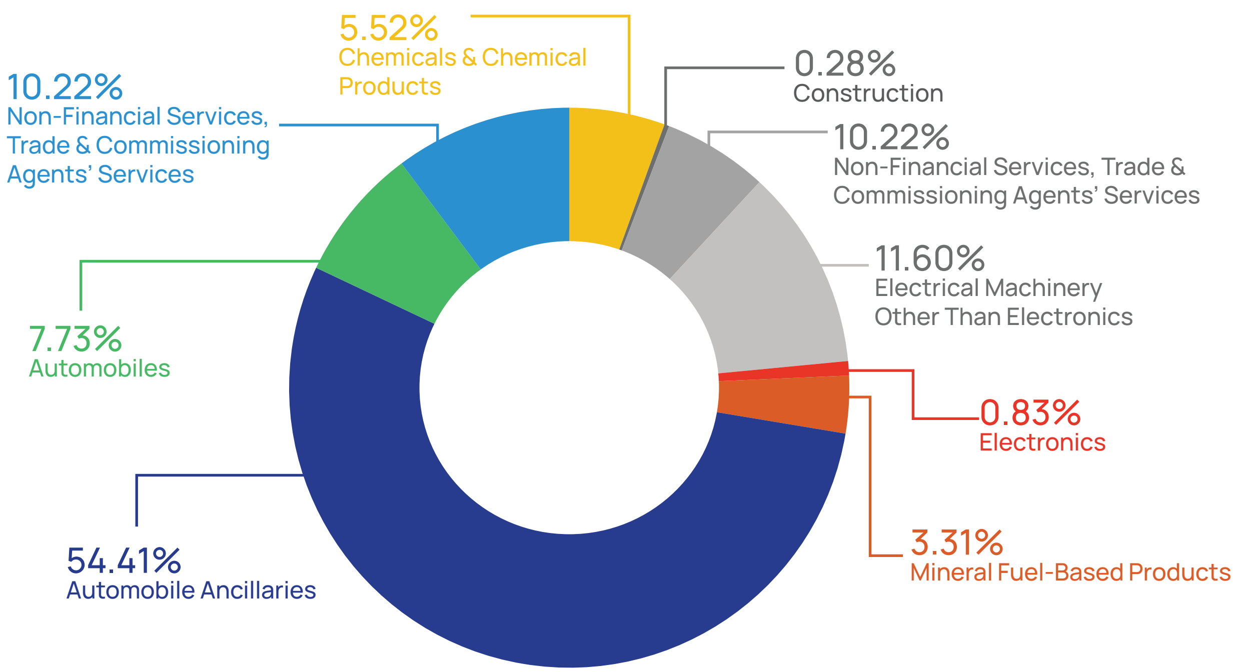
~ 54%

of manufacturers are involved in the manufacture of automobile ancillaries i.e., transport equipment



(e.g. drive transmission and steering parts, suspension and braking parts, automobile engine parts and so on), and the least amount (~3%) are involved in the manufacture of automobiles. However, from 2017-18 to 2022-23 shows that the maximum value addition has been by the meagre 3% involved in the manufacture of automobiles. This disproportionate distribution raises concerns, especially considering that the impending transition will significantly impact component suppliers.

Figure 10- Proportion of Stakeholders in the Indian Automobile Value Chain



Source- Authors' Analysis based on ProwessIQ Data Base.

[7] The dataset encompasses records from 364 companies, spanning the years 2018 through 2023. The year 2018 has been designated as the baseline for comparative analysis to integrate the impacts of the FAME I and II policies.

India holds a competitive edge in the auto components sector, particularly in categories such as shafts, bearings, and fasteners, owing to a significant number of players in these segments. This advantage is significant as these components remain crucial during the transition from internal combustion engines (ICE) to EVs. However, Indian companies lag behind in competitiveness in several key sectors, mainly due to inadequate investments in research and development (R&D) compared to global competitors[8]. A lack of substantial R&D investment, combined with insufficient collaboration between information technology firms and automotive manufacturers, leads to underutilization of India's robust software capabilities within the automotive sector (ACMA, Grant Thornton, 2023).

At a critical point where innovation becomes pivotal to securing a competitive advantage during the ongoing transition, the importance of integrating research and development with technology cannot be overstated. Policies or strategies aimed at facilitating this transition will fall short if the underlying technology fails to evolve concurrently. An analysis of different policies and ZEV mandates in various economies reveals that a mismatch between mandates and policies in countries like the US and China has posed a challenge in their transition. Unlike these economies, India faces a pressing need to act swiftly and decisively. Instead, India should be proactive in learning from these examples and strive to align research, development, and technology with the entire automotive value chain.

To tackle these challenges, strategic initiatives such as the Bharat New Car Assessment Program (BNCAP) have been introduced with the objective of strengthening the automotive value chain and concurrently fostering advancements in manufacturing and innovation (IBEF, 2023). Additionally, in tandem with these efforts, Production Linked Incentive (PLI) schemes specifically tailored for the auto components sector have been implemented, providing vital support for the establishment of manufacturing capabilities in the country. These combined measures represent a concerted approach to augmenting the automotive industry with broader objectives of technological advancement and self-sufficiency.

In contrast to global best practices where most Original Equipment Manufacturers (OEMs) are well-integrated or have established robust supply networks, India has yet to establish a strong supply base. More than 75% of the Indian

[8] Indian auto-component manufacturers historically allocated less than 3% of their revenue to R&D, whereas global majors dedicated a more substantial 6-10% of their revenue to research and development initiatives.

component industry players are tier 2 and tier 3 players. Despite their substantial presence, these players contribute proportionally less to the overall value chain compared to Original Equipment Manufacturers (OEMs). (ACMA, Roland Berger, 2018)

Electric vehicle components constitute approximately

60%

of the overall EV cost at present and are expected to remain above

50%

in 2025.

This imbalance in stakeholders of the value chain results in OEMs working in silos due to inadequate domestic component manufacturers, pose significant threats to their exports and local markets (ACMA, Roland Berger, 2018). This susceptibility is particularly concerning during transitions to new technologies, where weak linkages within the supply chain impede progress and foster dependency on other countries for crucial parts, components, and technology.
It is imperative to establish a balanced value chain where every stakeholder, irrespective of their tier, is sufficiently incentivized to remain in the industry and contribute meaningfully. Only through such incentives can robust linkages be formed, fostering a forward-looking industry capable of navigating technological transitions and reducing dependence on external sources.

To mitigate these risks in the Indian automobile ecosystem, it becomes imperative to incentivize suppliers and enhance their value addition to prevent high imports, and elevated manufacturing costs, resulting in a higher total cost of ownership, and ultimately impeding the goals of a successful EV transition. Setting a binding target with a focus on localisation can align the formulation of policies needs to be strategic, ensuring that stakeholders at each level of the value chain are aligned with the transition objective.

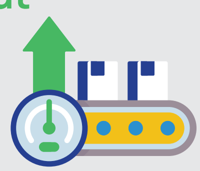
BOX – Crucial Role of MSME Participation in EV Value Chain.

India is acknowledged as a developing market and a prominent player in the automotive sector within the framework of global value chains (GVCs). India has shown significant engagement in both forward and backward global value chain (GVC) connections, namely in the field of producing transport equipment. This is demonstrated by the strong manufacturing capabilities of the Indian auto industry, which demonstrated the domestic value-added share of 74.8% in gross exports and 33.4% in total output for the year 2018. Furthermore, the industry's impact on India's GDP is significant, representing 7% of the total GDP and 49% of the manufacturing GDP in 2021.

2018

74.8% in gross exports

33.4% in total output



2021

7% of the total GDP

49% of the manufacturing GDP

However, the EV sector, being in its early stages, has not yet demonstrated equivalent performance. (OECD TiVA Database: Dash, 2023)

The Indian automotive component industry is predominantly comprised of Micro, Small, and Medium Enterprises (MSMEs), accounting for over 75% of the sector. These MSMEs are primarily categorized as Tier-II and Tier-III entities and play a crucial role as suppliers of parts and sub-assemblies to Tier-I players and Original Equipment Manufacturers (OEMs). Despite their significant presence, the lion's share of value addition within the EV value chain is attributed to the top 3% of OEMs. In order to adapt to the dynamic nature of the EV market in India, it is crucial for both Original Equipment Manufacturers (OEMs) and Micro, Small, and Medium Enterprises (MSMEs) to take proactive measures and fully engage in this transformative phase. MSMEs can improve their competitive advantage by diversifying their product range to include essential elements such as batteries, battery materials, electric motors, and power electronics, in addition to conventional accessories like electric motors and forged wheels. These enterprises must prioritise recognising market gaps and opportunities in the EV production process, such as the increasing demand for EV sensors and connectors driven by automotive manufacturers' integration of advanced sensor technologies to align with customer expectations and regulatory standards like BS-VI. By working together to develop new and creative ways of doing business and customising products for consumers, small and medium-sized enterprises (MSMEs) in the sector can tap into significant opportunities for growth. This can be achieved by making better use of manufacturing facilities that are not fully utilised. Moreover, enhancing their market position and sustainability endeavours can be achieved by attaining a competitive edge in domains such as charging infrastructure and the establishment of sustainable methods for battery repair and reuse (JSW, 2023).

To fully leverage these emerging opportunities, active research, development, and innovation are paramount. The absence of skilled labour hampers MSMEs' ability to innovate and successfully upscale their operations. Addressing this challenge requires strategic investments in vocational training programs tailored to the specific needs of the EV industry. Collaboration between industry and academia plays a pivotal role in bridging the skill gap and fostering a culture of continuous learning and adaptation. A notable example is the Tamil Nadu MSME EV Skilling Program, initiated by WRI India and FaMe Tamil Nadu, aimed at enhancing the capabilities of MSMEs and bolstering Tamil Nadu's stature as a leading hub for electric vehicle manufacturing. This training program is structured to provide hands-on, practical training opportunities for EV MSMEs and employees across all levels of the organization, including top management, middle management, and both skilled and unskilled labour (WRI India, 2023; TOI, 2023). Other states would benefit from emulating such specialized training programs to nurture a skilled workforce tailored to the demands of the evolving EV landscape.

The EV ecosystem exhibits a trajectory of growth and dynamism, where the economic and environmental contributions of any technological advancement are intricately linked to its widespread diffusion and adoption rates (Dash, 2023). However, the pivotal role played by MSMEs, constituting a significant proportion of manufacturers, cannot be overstated. Without proactive engagement and adequate support for MSMEs to capitalize on the burgeoning EV opportunities, the potential success of the EV ecosystem could face constraints, leading to either excessive import reliance or the dominance of a select few top-tier manufacturers. Such imbalanced growth patterns are inherently unsustainable and could hinder the holistic development of the EV sector.

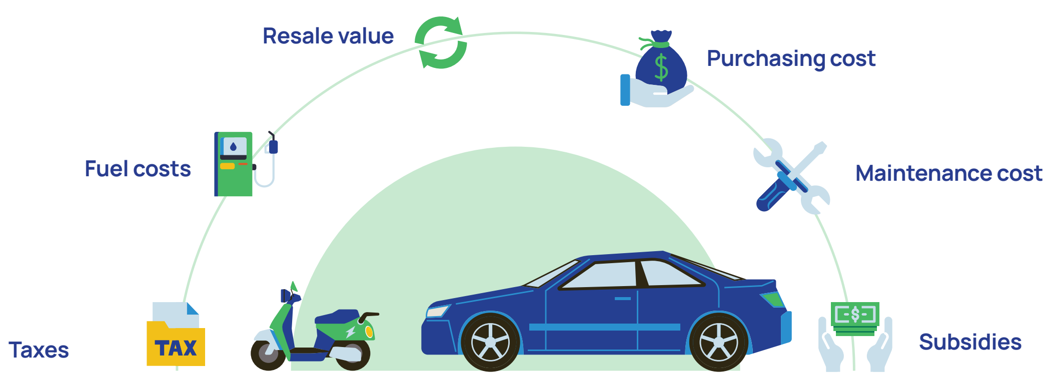
4.2 Major Impediments to EV Transition India

The comprehensive analysis of the automobile landscape, current policies, global practices, and the value chain underscores discernible gaps within the Indian automotive system. These gaps are critical impediments hindering the acceleration of India's automotive sector towards its e-mobility goals.

01 High Total Cost of Ownership (TCO) From Stakeholders and Policy Misalignment

The cost of a product to the consumer is not only dependent on the cost to the manufacturer but by the efficiency of supply and value chain integration, and the degree to which the product aligns with consumer preferences and budget. Cost of ownership is one of the most important factors affecting purchase intention, performance features, financial benefits, environmental concerns, social influence, and infrastructure support (Mishra & Malhotra, 2019). While analysing the cost of ownership, rather than solely assessing cost efficiency based on upfront expenditures, a more comprehensive perspective emerges when considering operating costs. This approach provides a realistic portrayal of expenses incurred throughout the vehicle's lifecycle. Total cost of ownership (TCO) amalgamates both purchase and operational outlays, facilitating the identification of the most economically viable vehicle choice. (Palmer and Tate, 2017).

In this research, an analysis of the Indian 2W and 4W vehicles is undertaken by analyzing the top-selling vehicles in both the two-wheeler and four-wheeler markets[14] considering parameters of purchasing cost, fuel costs, maintenance cost, taxes, subsidies and resale value. The analysis shows that demand-side subsidies have been successful in pulling down the upfront as well as the TCO for two-wheelers. Likewise, the combination of the FAME subsidy and technological advancements in electric 3W has yielded economies of scale. This has not only enhanced competitiveness in terms of TCO but has also diminished the purchase price disparity to less than 1.3 times that of a comparable internal combustion engine (ICE) model, thereby accelerating widespread adoption (Ramji & Kankaria, 2022). The penetration and cost efficiency of two and three-wheelers can also be attributed to the possibility of retrofitting



14. For Calculations, refer to Section 2 of the Appendix.

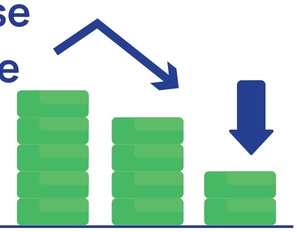
and the ease of Battery-as-a-Service especially for last-mile vehicles in these segments, which is difficult in passenger vehicles due to technological complexity.

However, in the case of four-wheelers, despite lowering of GST, exemption from other taxes, exemption on the registration fee, and income tax benefits, TCO remains high (even though about 25% lower than ICE counterparts). This, in turn, hampers the steady growth of penetration. Table 5 clearly states the differences in upfront costs and TCO of petrol, diesel and electric car.[9] EVs present a financially attractive option in the long term, primarily due to their substantially lower total cost of ownership (TCO). However, the initial purchase price remains prohibitively high for many consumers.

To make EVs more accessible, a significant reduction in the upfront costs, by approximately

30%-40%

is necessary to align the purchase price closer to the INR 8,00,000 range.



Though this figure is overly idealistic, it serves as a valuable benchmark for manufacturers to understand the extent of cost reduction needed to increase consumer affordability.

Table 5- Cost and TCO of different categories of Passenger Cars

Category of Passenger Car based on Fuel Type	Upfront Cost	TCO (Usage period 5 years at 15,000 km per year)
Petrol	13,32,842	13,19,140
Diesel	15,40,213	14,50,372
Electric (including exemptions)	15,43,905	10,62,843

Source- Authors' Calculations.

[9] The prices are on the basis of the best-selling EV in 2022 (TATA Nexon)

An examination of the Top 10 selling ICE passenger cars[10], which collectively represent 53.19% of the market, reveals that only two of the top 10 popular models fall within the INR 10-20 lakh range, while the majority of vehicles have an initial price ranging from INR 5-8 lakhs. There exists a stark contrast in price points between conventional ICE cars and available electric options, with just one EV falling within the INR 8 lakh range. This disparity poses a critical hurdle to the wider adoption of electric vehicles among the general consumer base. The existing scenario underscores a pressing need for the EV industry to strategize and innovate to bridge this affordability gap.

The resolution of the affordability gap mostly rests on whether demand-side incentives are employed to increase market share or whether supply chain and technology innovation are encouraged. The latter approach aims to achieve economies of scale, consequently reducing prices from the supply side. Although demand incentives in India are in line with best practices, improving production process efficiency and putting in place strong supply-side incentives are the keys to cutting upfront costs.

BOX- Replace, Improve, and Electrify Retrofitting for Rapid EV Penetration in the Short Run.

Despite a significant reduction in the total cost of ownership of an EV, high initial cost is a prime concern. As a solution, retrofitting[11] presents itself as a viable option in India's automotive environment. The global market for retrofit electric vehicle powertrains reflects the viability of this solution, with estimates predicting

a significant increase from USD 61.68 billion in 2022 to approximately USD 125.37 billion by 2032, indicating a

7.40%

compound annual growth rate (CAGR) between 2023 and 2032

While originally intended for considerable environmental benefits, retrofitting has gained popularity due to its potential to reduce running costs, particularly when compared to standard ZEVs. It enables the extension of the life of a petrol/diesel automobile that has reached its legal operational limit.

Retrofitting a four-wheeler results in significant savings. However, despite its financial appeal, the initial cost of retrofitting, ranges between INR 4-5 lakhs for standard four-wheelers. Furthermore, the introduction of more economical new-generation EV models, calls into question the cost-effectiveness of retrofitting older vehicles. Consumer willingness to invest in retrofitting, particularly for vehicles approaching 10-15 years of age, is further influenced by factors such as structural depreciation and the

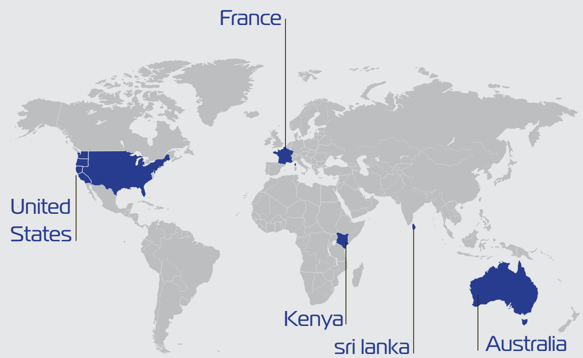
10. On the basis of October 2023 data.

11. The process of converting an existing petrol or diesel run vehicles into an electric vehicle by replacing engine and fuel tank with electric motor and battery (Government of Delhi).

expected longevity of modified vehicles in relation to break-even points.

Retrofitting offers a short-term solution to the high upfront costs associated with switching to EVs. However, it fails to address the issue of limited driving range. The only viable solution to range anxiety is larger batteries, which necessitate significant changes to a vehicle's body structure—changes that retrofitting cannot accommodate. A prime example is the recent introduction of EV-centric platforms by TATA and Hyundai, which support fast charging and larger battery packs, thereby extending vehicle range. Prioritizing retrofitting may yield short-term gains but could impede long-term innovation, essential for a sustainable electric future in India. Emphasizing new EV platforms fosters the necessary advancements to make EVs a more viable option in the future.

Retrofitting has proven to be a successful alternative in countries such as France, the United States, Australia, Kenya, and Sri Lanka, facilitating the conversion of old, pre-existing vehicles to electric power.



Economies with successful retrofitting models have implemented specific technical legislation for EV conversions, incorporated EV retrofits into existing EV incentives, and invested in research and development. These measures ensure that retrofitting progresses in alignment with evolving EV standards, promoting a seamless transition to electric mobility (GGGI, 2023).

02 Dependency on Demand Side Incentives.

The current landscape of both central and state policies highlights a significant reliance on demand-side incentives. While there are supply-side initiatives such as the Production-Linked Incentive (PLI) and programs aimed at developing the ecosystem, their impact remains limited in terms of reach and efficiency. It's crucial to recognize that demand-side policies which align with global best practices, possess inherent limitations and overemphasis on them could strain government finances and prove unsustainable. Moreover, these policies do not directly influence fundamental elements like manufacturing costs, technology, or innovation, that are essential for cultivating a robust ecosystem.

Addressing this challenge necessitates a strategic shift towards manufacturing incentives that not only streamline processes but also drive India towards sustained growth and innovation.

03 Lack of singular target and mismatch between state targets

In the context of India's endeavours to electrify its vehicular fleets, systemic inefficiencies emerge due to disjointed initiatives across the sector's various components. The government's role is critical in facilitating the attainment of electrification benchmarks through fiscal incentives and subsidies. However, the absence of explicit performance benchmarks for vehicle manufacturers and component suppliers engenders an imbalanced strategic approach. This scenario is reminiscent of the early stages of electric vehicle policy development in other nations. For instance, a deficiency in long-term policy clarity coupled with dispersed regulatory oversight initially led to uncoordinated micro and macro-level policies in China (Li, Yang, & Sandu, 2018). Analogously, in the United States, a misalignment between policy initiatives and comprehensive market analysis contributed to delayed market penetration, as investments did not resonate with consumer predilections and price sensitivity (Green, Skerlos, & Winebrake, 2013). Subsequent policy restructuring in these countries has been pivotal in establishing more efficacious electric vehicle strategies.

While it is crucial for each state to tailor policies according to its unique political and economic conditions, a coordinated effort is essential to ensure a unified direction and collective goal attainment. Presently, the absence of checks and balances in the overall aims hinders effective monitoring, potentially leading to a misalignment of efforts and stifling progress toward the shared goal.

Establishing clearer, measurable targets for all stakeholders and implementing robust monitoring mechanisms will be key to enhancing efficiency and achieving successful electrification outcomes across the nation.

The high discordance between policies, stakeholders and segments within the automobile ecosystem signifies the need for a unified approach in order to keep pace with the climate and economic goals. At this stage, it is important to turn our attention focus to the effects of targeted initiatives such as the ZEV mandate, which has been instrumental in the transitional strides of major economies and consider its potential impact within the Indian context.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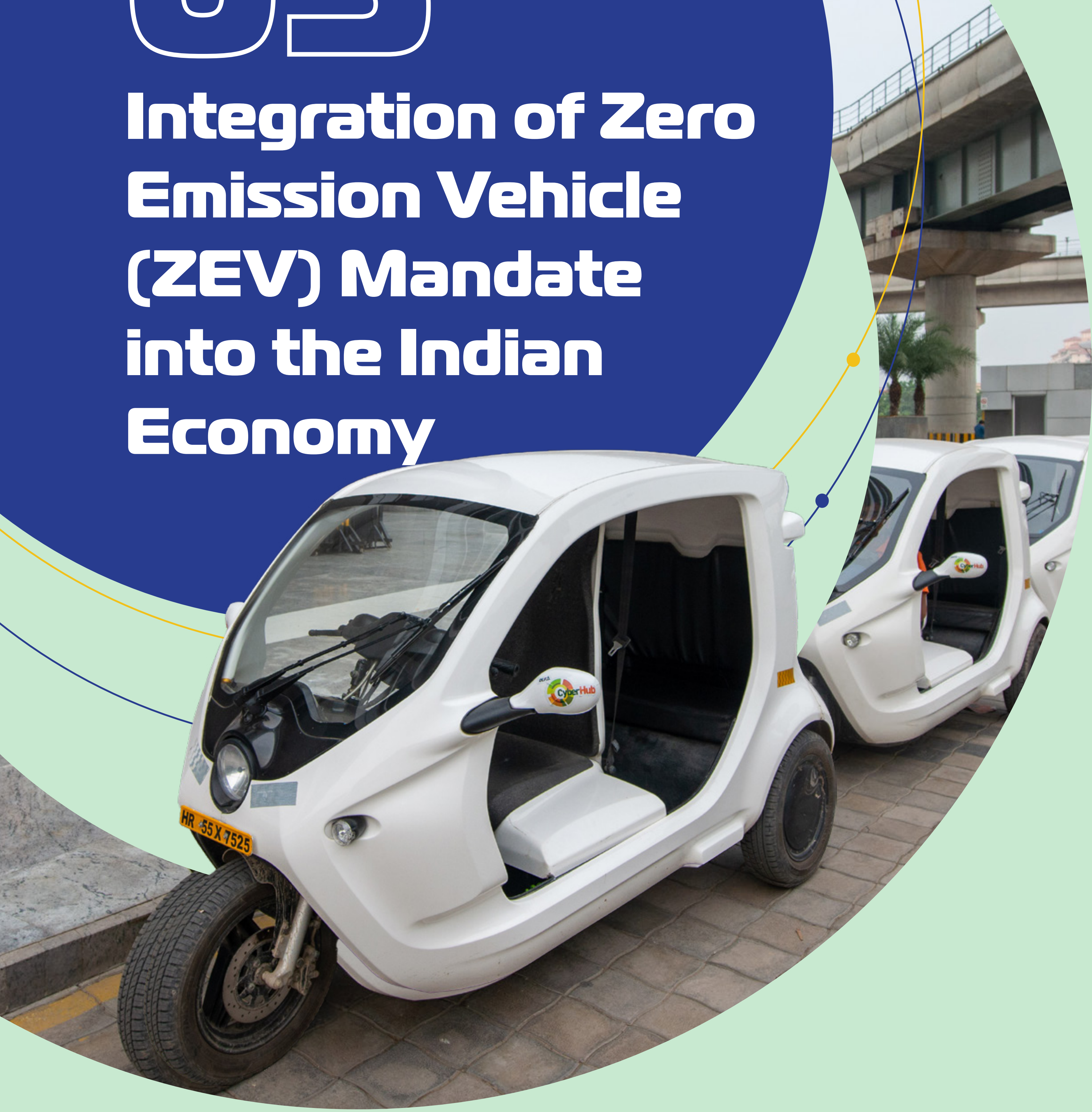
05

Integration of Zero Emission Vehicle (ZEV) Mandate into the Indian Economy



The introduction of the ZEV mandate signifies a pivotal stride towards the widespread adoption of electric vehicles in numerous countries, all sharing a common objective – to catalyse and expedite the transition to electric mobility. The mandate delineates a comprehensive strategy, encompassing multiple phases, benchmarks, deadlines, and penalties. This meticulous framework ensures that all stakeholders in the automotive industry are collectively steering towards a shared goal, fortified by unwavering governmental policy support.

In the context of India, where the momentum for electric vehicle adoption is gaining traction, it becomes imperative to harmonise and integrate targeted efforts. This integration is crucial for positioning the nation competitively within the global movement towards sustainability. Nevertheless, a unique perspective must be applied to India, acknowledging the disparities between India and other nations that have implemented the ZEV mandate.

These disparities manifest across various facets, including manufacturing capabilities, integration with global value chains, and a substantial reliance on internal combustion engine (ICE) vehicles. India is, thus, compelled to tailor its approach judiciously, drawing insights from the triumphs and tribulations of other nations' policies rather than duplicating them verbatim. It is within this context that we delve into the exploration of a mathematical model to scrutinise the potential implementation and ramifications of the ZEV mandate in the Indian context.

This section of the report will pave the way for a comprehensive discussion on the requisite investments and policy adjustments. These adjustments are paramount for the successful transition towards a ZEV-centric automotive landscape in India. The subsequent section of this report will focus on the multifaceted dimensions of this transition, examining the interdependence of economic, infrastructural, and regulatory factors.

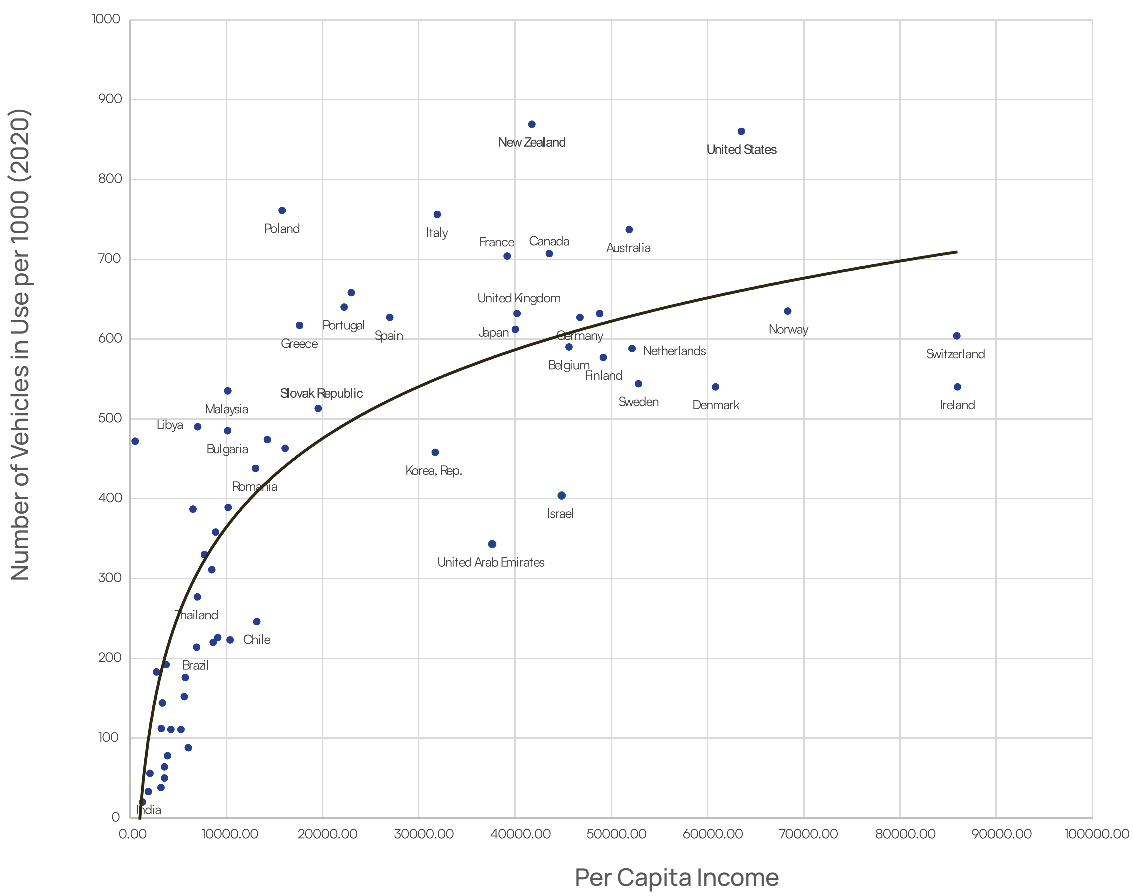
Moreover, it is essential to anticipate and address the implications of a ZEV mandate for India's vehicular policies and automotive aspirations. The dynamic nature of the automotive market, coupled with evolving consumer preferences, necessitates a strategic evaluation of how such a mandate would reshape the landscape. This foresight is essential for coordinating current policies and goals with the ZEV mandate's trajectory in order to ensure a cogent and sustainable evolution of the Indian automotive industry.

5.1 Factors Determining the Success of the ZEV Mandate

When considering the implementation of a production mandate, it is crucial to ensure that market conditions and the stage of economic development align with the policy. Premature or delayed policy implementation can fail to achieve the intended outcomes and disrupt the growth trajectory.

The ZEV mandate is a strategic and focused directive designed to increase the penetration of EVs. The successful uptake of EVs depends on their ability to meet market demand and align with the income profiles and budget constraints of consumers. Changes in production or policy must account for the demand elasticities of the product, especially in the context of vehicles, which exhibit positive income elasticity, i.e. the likelihood of purchasing a car (car sales) increases when income, particularly disposable income, rises (Linn & Shen, 2021; OECD; Lescaroux, 2007). There is a strong correlation[12] between purchasing power (calculated by GDP Per Capita) and automobile sales, particularly cars. This relationship has been evident across various economies at different stages of development and income levels (Dzuro, 2023; OECD; Chin, 2004; Cragg & Uhler, 1970; McCarthy, 1996; Lescaroux, 2007).

Figure 11- Correlation between per Capita Income and Vehicle per 1000.



Source- World Bank.

12. The strength of the correlation decreases after a threshold of per capita income.

Market penetration is not only determined by the average rise in income but also by improvement in the reduction of income disparities in an economy. Low average income coupled with high income inequality results in a divided and polarised market, with a clear distinction between low-quality and pre-owned automobiles on one end and luxury cars on the other (Köhler & Jiménez, 2012). To achieve widespread acceptance, it is essential to address income inequality, enabling individuals from lower socio-economic backgrounds to transition into the middle class and become potential automobile purchasers. Without this shift, car purchases remain limited to the wealthy resulting in a stagnant overall adoption rate.

The surge of production, as a result of the ZEV mandate, will only be absorbed if it falls within the budget constraints of the consumers. The automobile will fall in the price range only if economies of scale are accrued by the producers.

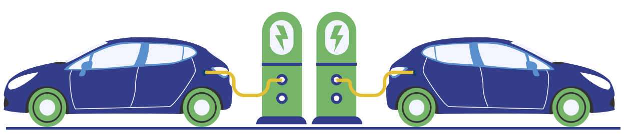
Achieving this goal can be approached in two ways – increasing per capita income or improving manufacturing infrastructure to reduce production costs.

While boosting per capita income is complex and influenced by many macroeconomic and sociological factors, making it a slow process, reducing production costs is more feasible and falls under the purview of the automobile industry. This can be done by enabling manufacturers to produce cost-effective and advanced products through better infrastructure and innovation. Although government support is essential, private players must also take significant action. A Zero ZEV mandate could drive manufacturers to create quality cars that are both affordable, meet consumer needs, and fit their income profiles.

Significant insights can be derived from economies that have successfully implemented the ZEV legislation. Initially implemented in California, China eventually adopted this strategy. Both economies enforced the mandate to address domestic demand, driven by successfully implemented policies designed to achieve their national environmental and production objectives. The mandate subsequently became a highly efficient mechanism by offering technologically advanced and economically viable automobiles. China's implementation of the ZEV mandate is comparatively more successful than California's and has proven to be highly effective, establishing itself as a prominent producer of EVs. China not only meets the domestic demand for EVs but also emerged as the largest exporter of EVs. Examining China's experience is valuable for India, given that both countries started as developing economies with similar income levels. However, China has advanced significantly in the automotive sector, particularly in EVs, outpacing India. Extracting key takeaways from China's journey, from a similar starting point to becoming a major player in the EV market, can provide crucial insights into India's development in this industry.

China initiated its EV journey in 2000. Through small policy efforts included in their Five-Year Plans, they eventually launched their first flagship program, Ten Cities Ten Thousand Vehicles (TVTC), in 2009.

By this time, 10.33 million passenger vehicles were sold in the Chinese market, indicating substantial demand and penetration of Chinese cars.

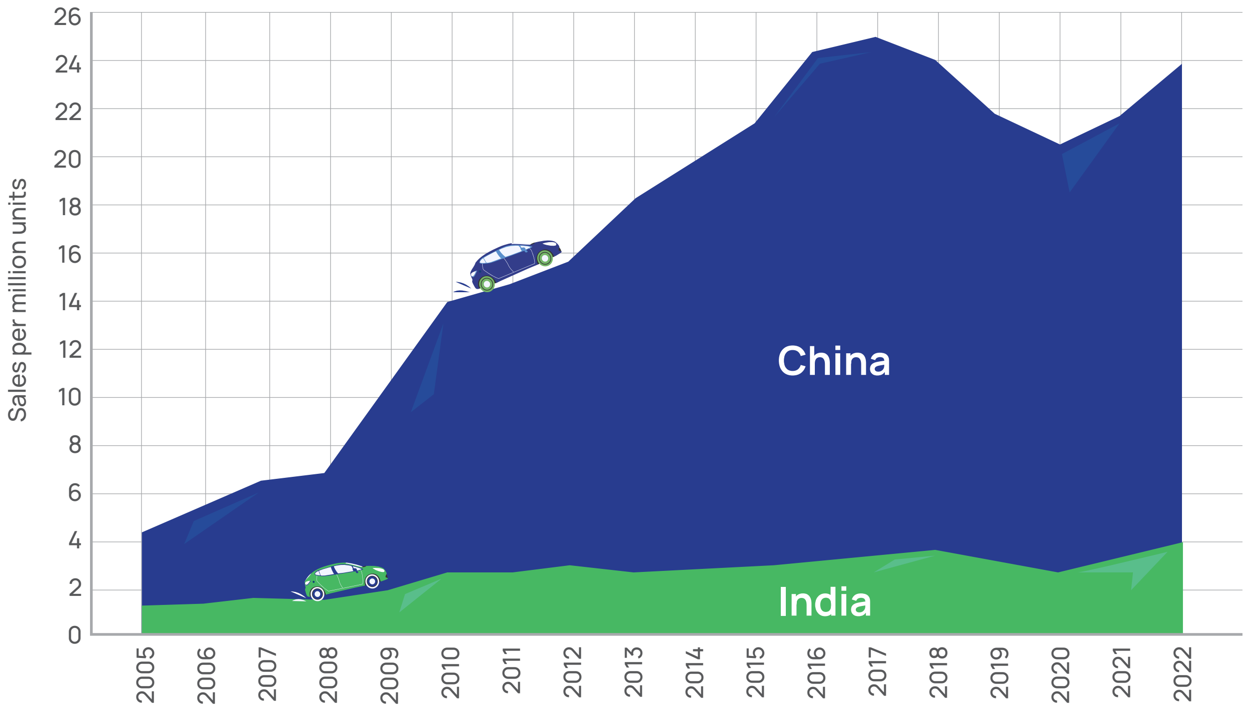


To cater to this increasing demand and to further bolster its EV initiative China implemented the ZEV mandate in 2017, when passenger vehicle sales had surged to 24.72 million, reflecting a 139% increase from 2009. In contrast, India introduced its first major EV policy, the National Electric Mobility Mission Plan (NEMMP), in 2013—four years after China's TVTC program.

In 2013, India sold 2.55 million passenger vehicles, a market size four times smaller than China's.

The gap between the size of the automobile markets in India and China has widened significantly. This divergence can be attributed to China's rapid and robust growth contrasted with India's comparatively stagnant and slow-paced expansion. By 2022, China sold 23.56 million passenger cars, with 29% being EVs, while India sold 3.79 million passenger cars, with approximately 5% being EVs—about one-sixth of China's sales. It is crucial to understand the key factors that enabled China to not only expand its overall automobile market but also achieve rapid growth in its EV market compared to India.

Figure 12- Size of Automobile Market in China and India



Source- Statista

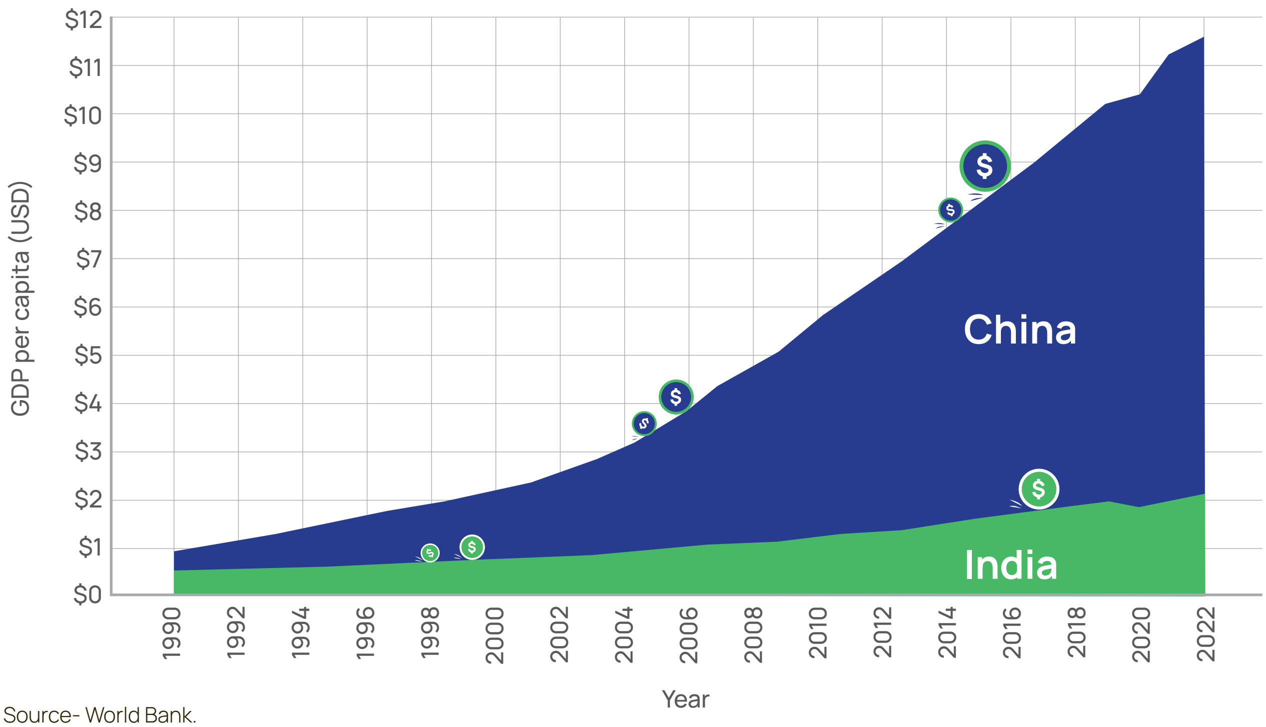
Major Factors Responsible for Divergence of Automobile and EV Market Growth in China and India

a) Disparities in Purchasing Power

The difference in passenger vehicle sales (ICE or EV) between China and India can be largely attributed to the varying purchasing power of their populations. The inception of ZEV research in China in 1991 occurred at a time when its per capita GDP was approximately twice that of India's, standing at USD 905.03 and USD 534.48, respectively. Over the years, China's per capita GDP surged, reaching around five times that of India by 2013, highlighting a widening economic disparity. This gap has since slowed down but widened further, with the ratio increasing to 5.53 as of 2023. Such a substantial difference in per capita GDP results in a significant difference in purchasing power among the populations of these two nations, which directly influences market demand dynamics and the ownership patterns of passenger vehicles. Examining per capita vehicle ownership reinforces this argument; in 2020, China boasted 233 vehicles per 1000 inhabitants, whereas India's figure was a mere 33.

In the current Indian market, EV variants are priced higher than internal combustion engine (ICE) variants. Given the prevailing per capita income levels, the penetration of cars, particularly EVs, remains relatively low. To substantially increase EV adoption and enhance their market share, it is imperative that EVs become more economically viable and competitive within the automotive sector.

Figure 13- GDP Per Capita of China and India



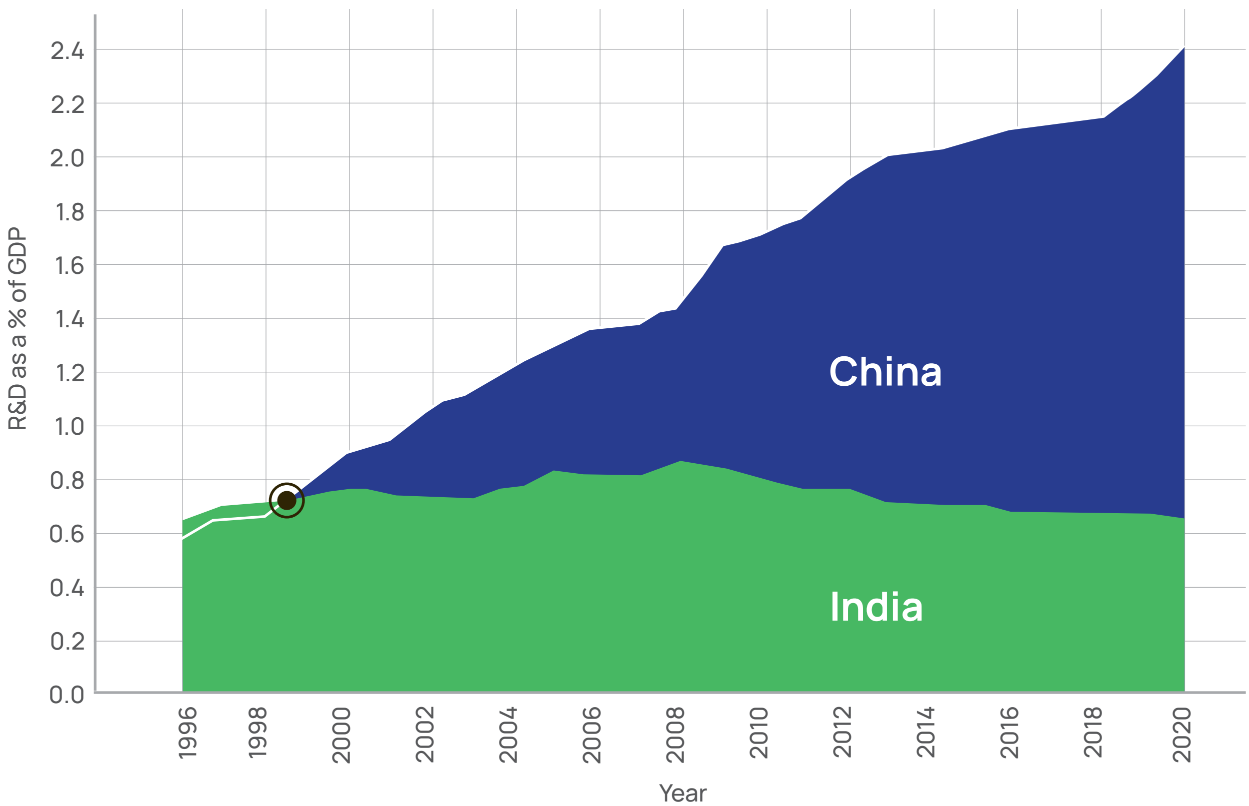
Source- World Bank.

b) Impetus on Research, Development and Technological Advancement.

In recent years, the global automobile sector has undergone significant transformations due to technological advancements, necessitating continual adaptation to remain competitive and efficient. This dynamism is particularly evident in China, where proactive approaches have propelled the automobile industry towards pioneering advancements, notably in ZEVs. The pivotal role of research and development (R&D) efforts, both from the private and public sectors, cannot be overstated in fostering such advancements and aligning with evolving consumer preferences and industry trends.

Initially, in 1996 India exhibited a higher share of R&D expenditure as a percentage of GDP than China, but China's consistent and escalating R&D investments, reaching 2.43% of GDP in 2021, have surpassed India's, which peaked at 0.86% in 2008 before declining 0.6 in 2021. The impact of this divergence is evident in the global automotive market. China's cost-effective and technologically advanced cars have propelled its dominance in vehicle exports, surpassing Japan as the largest exporter of passenger automobiles in 2023. In contrast, India's lower R&D investment is mirrored in its limited export performance, underscoring the critical role of R&D expenditure in enhancing export competitiveness and sectoral expansion. The correlation between R&D investment and industry competitiveness underscores the strategic imperative for economies to prioritize technological innovation and R&D expenditure in the automotive sector. Beyond domestic market dynamics, the ability to compete and thrive in the global automotive landscape hinges significantly on sustained R&D efforts, ensuring ongoing technological advancements, market relevance, and international competitiveness.

Figure 14- R&D expenditure as a percentage of GDP of China and India



Source- World Bank.

c) Promoting Market Diversity by Facilitating Entry for Multiple Players

The Chinese vehicle industry's vast scale is attributed to the substantial number of manufacturers operating within its borders, exceeding 150 automobile brands. This landscape comprises approximately 60% domestic manufacturers and the remaining entities in partnerships with foreign corporations. Notably, many domestic firms in China benefit from governmental control or substantial support during their inception stages. Such governmental backing has facilitated their global expansion, allowing significant investments in research and development (R&D) and the advancement of cutting-edge technologies to enhance production processes. In contrast, India's automotive sector showcases a limited presence, with only 17 major passenger car manufacturers, primarily dominated by Maruti Suzuki India, Tata Motors, and Mahindra & Mahindra. The industry's growth trajectory in India is hindered by the concentrated market structure, underscoring the importance of fostering a more diverse and competitive environment. While India cannot replicate China's state-owned enterprise model due to differences in governance structures, it could emulate the capacity-building strategies that have propelled Chinese small firms into national players. This strategic shift could address concerns related to competition, production costs, and sectoral expansion, ultimately fostering a more dynamic and robust automotive industry.

The current landscape in India's EV manufacturing sector reflects a steady rise, coinciding with substantial demand for cars. This upward trend increases in market penetration will improve the supply-side factors aligned with demand conditions. The equilibrium point, where suppliers can capitalize on economies of scale while meeting domestic demand, hinges upon several critical factors. There must be a concerted effort towards specific and focused capacity building in manufacturing, encompassing infrastructure and technological advancements for EVs, facilitated by collaborative initiatives between governmental bodies and private enterprises. Policies like the ZEV mandate compel private entities to channel investments into research and development, to develop cutting-edge technologies and efficient production methods to offer competitively priced EVs that are accessible to a broader demographic. This synergy initiates a positive feedback loop wherein increased EV automobile sales bolster demand, subsequently enhancing profit margins through economies of scale once optimal production costs are attained.

Consequently, competitors are incentivized to introduce progressively advanced and cost-effective vehicles to capture market share. This will facilitate the replacement of internal combustion engine (ICE) vehicles with EVs as the more financially viable option, benefiting both producers (through cost efficiency) and consumers (through a lower total cost of ownership). This transition aligns closely with the economic and environmental objectives set for the Indian economy.

As technological prowess grows and domestic sales targets are met, India stands poised to become a significant player in the global automotive market, potentially expanding its reach through automobile exports. Therefore, the ZEV mandate emerges as a pivotal intervention, obligating manufacturers to prioritize technological and cost efficiencies, thereby fostering market penetration, and improving its significance in the global EV market.

BOX – Key Role of Charging Infrastructure in Accelerating EV Adoption

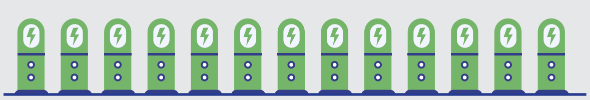
The rapid increase in EV sales can be sustained by expanding infrastructure to ensure convenience and affordability making it a convenient and practical choice for a larger population. Government and private investment in both public and private charging infrastructure are crucial for minimizing barriers to EV adoption. Meeting charging demand with accessible and affordable infrastructure, whether at homes, workplaces, or public stations, is essential to maintaining momentum in EV sales.

Globally, over 600,000 public slow charging points and 330,000 fast charging points were installed in 2022, with nearly 90% of this growth occurring in China.

As of March 2024, India has

27,471

charging points across 16,334 public charging stations, with 12,146 public EV charging stations nationwide (OMI Foundation, 2024; PIB, 2024).



As EV adoption increases, the EV-per-charger ratio is a critical metric for assessing charging network adequacy. Countries like China, Korea, and the Netherlands have maintained fewer than ten EVs per charger in recent years, while India has 135 EVs (PVs and 2Ws) and 86 EVs per charging station for 3Ws. In countries that rely heavily on public charging, the number of publicly accessible chargers has expanded at a pace that matches EV deployment. Conversely, in markets with widespread home charging availability, due to a high prevalence of single-family homes equipped with chargers, the EVs per public charging are greater in number. This contrast highlights the importance of a balanced approach to charging infrastructure development, tailored to the specific needs and characteristics of each market, to support the sustainable growth of EVs (IEA, 2023).

India aims to achieve 30% EV penetration in passenger vehicles by 2030, necessitating approximately 1.32 million chargers within the next 6-7 years (Anand, 2023). To meet this goal with a modest target of 40 EVs per charging point, the country must significantly accelerate infrastructure development, given the current number of chargers. Despite substantial growth in home charger installations, public charging spaces, particularly along national highways and long routes, are essential for enabling long-distance travel. Beyond the number of chargers, the cost of charging and exemptions from electricity charges are critical to reducing EV maintenance and fuel costs. Almost all states have defined targets for penetration of charging infrastructure as well as incentives for developing charging infrastructure (Figure 15) (Climate Trends, 2023).

Figure 15- Charging Infrastructure Incentives

Punjab
Targets

30,000 by 2024

Incentives

Incentive between ₹3000-10000 per Charge Point depending on level of charger

Haryana
Targets

Incentives

One time subsidy of 20% of Fixed Capital Investment

Gujarat
Targets

Incentives

Capital Subsidy of 25% of the value of the charging station equipment /machinery up to a maximum subsidy of ₹10,00,000

Maharashtra
Targets

2500+ charging stations in top 5 cities by 2025

Incentives

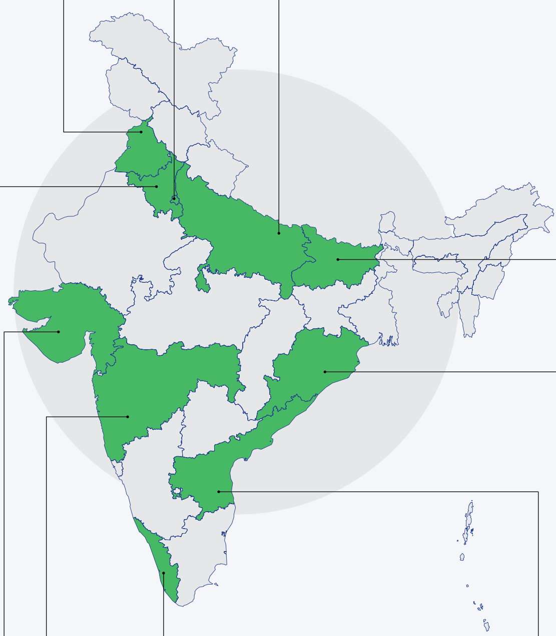
For Slow chargers 60% of the cost or ₹10,000 max and for Moderate/fast chargers 50% of the cost or ₹5,00,000 max

Delhi
Targets

30,000 charging stations

Incentives

Provision of 100% grant for the purchase of charging equipment up to ₹6000 per charging point.



Kerala
Targets

400 charging stations by 2022

Incentives

Capital Subsidy of 25% of the value of the charging station equipment/ machinery or a maximum subsidy of ₹10,00,000 for stations above 100V and Capital Subsidy of 25% or ₹30000 max for station for below 100V

Uttar Pradesh
Targets

2,00,000 slow and fast charging, swapping stations by 2024

Incentives

A capital subsidy of 20% of total cost or subject to maximum ₹10 lakh per unit station

Bihar
Targets

250 charging stations by 2024

Incentives

Capital Subsidy of 25% of the value of the charging station equipment/machinery up to a maximum subsidy of ₹5,00,000

Odisha
Targets

Incentives

A subsidy of ₹5000 per charger

Andhra Pradesh
Targets

1,00,000 slow and fast charging stations by 2024

Incentives

Capital Subsidy of 25% of the value of the charging station equipment/ machinery or a maximum subsidy of ₹10,00,000 for 100 V & above for 100 stations Capital Subsidy of 25% of the value of the charging station equipment/machinery or a maximum subsidy of ₹30,000 for 100V & below

Source - (Agarwal & Pathania, 2024) (Punjab Transport Department, 2023) (Government of Maharashtra, 2021) (NITI Aayog, 2021) (Climate Trends, 2023) (Government of Haryana, 2022)

However, none of the states are on track to meet their charging infrastructure targets. Delhi, with the highest number of charging stations in the country, has only achieved 9.67% of its charging infrastructure target of 30,000 charging stations by 2024 (Climate Trends, 2023). Charging investments by key private players like TATA Power Company Limited, Charzer Tech Pvt. Ltd., Mass Tech Controls Pvt. Ltd., and Exicom Telesystems Ltd along with the aforementioned government initiatives are gradually improving the state of charging infrastructure of the nation.

Establishing a robust charging infrastructure is crucial to combat range anxiety and accessibility issues which stand as one of the major impediments towards EV adoption. Furthermore, despite the rise in home charger installations, public charging stations, especially on national highways and major routes, are essential for facilitating long-distance travel and public transportation.

BOX – Potential of CAFE Regulations in Improving Fuel Efficiency and EV Penetration

In recent years, emissions from the vehicle industry have become a major environmental concern. To address this issue, many countries have set Corporate Average Fuel Economy (CAFE) regulations in their automotive industries. CAFE standards set limits on the average amount of greenhouse gases, primarily carbon dioxide (), emitted by a car manufacturer's fleet of vehicles sold in a specific year. These restrictions not only contribute to a cleaner environment but also encourage the development and adoption of EVs, paving the way for a ZEV future.

The genesis of CAFE standards traces back to the United States, which pioneered the concept in 1975. Since then, these standards have evolved with progressively stringent targets.

Projections suggest that by 2030, these standards could slash global warming pollution by a staggering

570 metric million tonnes

570 metric million tonnes

Following suit, the European Union (EU) adopted its inaugural voluntary emission performance standards for new passenger cars in 1995, mandating them in 2009. Initially, these regulations mandated only the display of fuel efficiency and emissions data during marketing, but they swiftly transitioned to enforceable emission-based targets. Notably, vehicles below these emission limits received super multipliers to further incentivize their sale (IEA, 2021). Both the US and EU employ tradeable CAFE credits, motivating manufacturers to accrue credits by producing a maximum number of EVs.

China, as the world's largest car market, enacted its first fuel consumption standards in 2005. Subsequently, China's passenger vehicle fuel consumption standards progressed through five phases (I-V), each intensifying in stringency (Transport Policy). Phase III in 2012 introduced Corporate Average Fuel Consumption (CAFC) standards, requiring manufacturers to meet an average fuel efficiency target across their fleet alongside per-model standards. Currently, China is in Phase V and has shifted to a more realistic testing cycle as well as transition from weight-class-based limits to a weight-based linear regression calculation. Further, the credit policy introduced in 2017 enhanced energy efficiency and ZEV penetration in China.

In India, Phase I of the CAFE regulations was launched in 2017 for a 5-year period setting a target of

130gm/km

emissions for automobile manufacturers.

In Phase II, beginning 2022, the norms have been made stricter by introducing a target of 113g/km (Council on Energy Environent and Water). These norms hinge on average curb weight, thereby assigning higher CAFE targets to heavier vehicles (Shah, 2023). The CAFE regulations also have provisions for super credits which are awarded to manufacturers based on the production of ZEVs. Every BEV sold by the manufacturer is counted as 3 units sold, every PHEV as 2.5 units sold and HEVs as 2 units sold. The system also rewards innovation in fuel-saving technology by counting cars with regenerative braking, a start-stop system, a tyre pressure monitoring system and a 6 or more-speed transmission leading to a lower figure for the manufacturer (Autocar India, 2022). As of the end of Phase I, all the manufacturers in the Indian market have been able to achieve their CAFE targets according to the Annual Fuel Compilation Report by the Bureau of Energy Efficiency. As the limit in the current Indian standards is low, the manufacturer is able to achieve the CAFÉ targets without producing any EVs (Bureau of Energy Efficiency, Ministry of Power, GOI; Autocar India, 2022).

The motive of CAFE regulations is not only to reduce emissions but also to create a market environment conducive to the development and adoption of EVs. While India's CAFE regulations have shown some success in improving vehicle fuel efficiency, their effectiveness in promoting EVs and ZEVs remains limited, as the auto manufacturer does not have to produce EVs to achieve the target but can simply do so by improving the fuel efficiency of the existing ICE vehicles. To truly incentivize ZEV adoption through CAFE, India can consider a two-pronged approach:

FIRSTLY, stricter CAFE targets, similar to those implemented in the EU with their 95 g/km limit, would put greater pressure on manufacturers to invest in cleaner technologies. This would push them beyond simply improving internal combustion engine efficiency and force them to consider ZEVs as a viable solution for meeting emission reduction goals.

SECONDLY, implementing a tradable credit system for CAFE compliance, like China's program, could further incentivize ZEV production. Under such a system, manufacturers exceeding their targets could earn credits tradable with those falling short. This would create a market value for ZEVs, as they would generate the most credits for manufacturers. This economic incentive, coupled with stricter targets, could significantly accelerate the shift towards ZEV production in India.

As India navigates its path towards a ZEV future, strengthening CAFE regulations can be a critical stepping stone. By establishing stricter targets and introducing tradable credits, India can encourage the auto industry to embrace ZEVs. This will pave the way for a smoother transition towards a ZEV mandate in the future, allowing the market to mature and the industry to prepare for a zero-emission transportation landscape.

5.2 Model

The preceding section delves into a qualitative comparison between India and China, outlining essential steps and potential implications of the mandate. This section provides an outline of a mathematical model to examine the impact on the Indian economy in case a ZEV mandate comes into effect.

The main objective of the model is to evaluate the total influence of the ZEV mandate on prominent vehicle manufacturers in India. We analyze the evolution of the production composition of these automakers using simulation in order to adapt to the regulatory change. This offers insights into the modifications and accommodations that original equipment manufacturers (OEMs) will have to make in order to comply with the required production levels. Furthermore, the model provides information regarding the efficacy of the ZEV mandate policy in promoting the use of zero-emission vehicles in India.

Given the paucity of literature on the impact of a ZEV mandate in a market in the context of developing economies, its feasibility and applicability in the context of India have been not explored currently. This makes our model the first attempt to understand its applicability to India as a nation. ZEV mandate has not been thoroughly contemplated by legislators and researchers in the country. In China, extensive research has been conducted on the impact of its dual credit policy and other measures aimed at increasing the adoption of EVs in the market. Yaoming Li, (2018) analyses the impact of dual credit policy on vehicle manufacturers in the country using a game theory-based optimisation model. The study shows that enacting a ZEV mandate is always better than purely providing production subsidies to the manufacturers in the country. A similar analysis conducted under the study (Shiqi Ou a, 2018) found the dual credit policy in

the Chinese automobile market to be beneficial for increasing the share of battery electric vehicles as compared to other policy scenarios in the simulation for the period 2016-2020. Similar studies have been conducted in other countries as well. Under a study of the Canadian Automobile Market, (Chandan Bhardwaj, 2021), an Automaker Consumer Model was developed to analyse the demand and supply side effects on the automobile market upon the introduction of a ZEV mandate of 30% EV production. Their study concluded that even with the implication of the mandate, almost all the automakers in the market would be able to meet the target mandated by the government but this would lead to a reduction in the profits of the automakers by 7%-44%. This report attempts to construct a model to understand applicability of the ZEV mandate in India.

5.3 Model Description

This report employs a non-linear optimization approach to simulate the effects of a mandated policy on the production decisions of various automakers in the market. The objective function of the model is to maximize the total profit for each participating firm. Additionally, linear constraints are incorporated into the optimization problem to accurately illustrate the impact of the mandate. This model, designed specifically for the Indian automotive industry, incorporates the ZEV regulation to assess its potential consequences on domestic four-wheeler producers. The model presupposes that the manufacturers are obligated to meet a ZEV mandate of 30% of their total production.

Requiring that at least 30% of vehicles manufactured are ZEVs is in line with the Indian Government's goal of attaining a 30% market share for ZEVs in the Indian market by 2030.

Every car manufacturer is required to comply with this directive, which means they must produce 30% of their vehicles as ZEVs. Each ZEV unit produced by a manufacturer earns the manufacturer two ZEV credits from the government, which can be traded in the credit market. This is a new element of the mandate policy in the country as the current super credits earned by the manufacturer based upon CAFE regulations in terms of production of zero-emission vehicles are not tradable in the current system. The allocation of two credits for ZEV manufacturing is derived from the practice observed in other nations, where ZEV credits are exchanged and bestowed upon manufacturers. Each country employs its system for distributing credits based on the classification of vehicles, including BEVs, PHEVs, hybrid vehicles, and others. The report assumes a constant credit of two units for all types of ZEVs. The target of ZEV credits for each automaker is governed by a specific equation:

Target ZEV Credits = 2 x 0.3 x (Total production of vehicles by the firm).

Any excess credits earned can be traded in the market. However, credits earned within a financial year are based solely on the manufacturer's production volumes for that year. Banking or carrying forward credits from previous years is prohibited, rendering redundant any excess credits left with the manufacturer after compliance and trading. Automakers failing to meet their credit targets must purchase the remaining credits from the ZEV credit market. If an automaker fails to fulfil its ZEV credits target, then it would be penalised by the Indian government in the form of a heavy monetary penalty.

The model incorporates the aforementioned factors and is constructed based on a set of parameters, constraints, and assumptions that account for the market's complexity and limitations. This approach aims to identify and quantify the impact of supply-side mandates and focuses on the two-wheeler (2W) and four-wheeler (4W) vehicle segments (Refer Appendix- Section 3 for the equations and details of the model). However, the simulation of the constructed model is restricted due to data constraints detailed in the next section (Section 5.4).

5.4 Discussion and Limitations of the model

This model represents a pioneering effort to mathematically predict the effects of implementing a ZEV mandate in India, a discourse previously unexplored within the Indian economy. Building on foundational research centred around ZEV mandates in Chinese and US markets, this model serves as a tool for policymakers, automakers, and government officials to align with India's electric mobility goals.

However, while attempting the application of this model to the Indian economy, we faced several data challenges. Currently, India is in the nascent stages of its EV industry, which has gained traction only in the past decade. Consequently, the implementation of this model is restricted to data from 2018-2023. ProwessIQ is one of the few sources collating financial information of companies, including revenue, sales, income, change in stock, expenses and so on. However, the specific financial data required for this model, particularly cost variables, is unavailable. The model relies on a cost function to determine changes in profit and production due to the mandate. Without cost data, formulating this function is nearly impossible. Attempts were made to use data available on ProwessIQ as proxy variables for cost, but fundamental differences in concepts and discrepancies in data even in these variables did not allow us to employ these variables.

Another significant impediment is the inconsistency in production and price data. The data of the ICE vehicle producers had inconsistencies, which reduced the pool of usable companies after data cleaning. On the EV front, there are only seven significant players[19] in the market, even within this small group, data inconsistencies were prevalent. This dearth of data on major variables like costs and production complicates the application of the model in the Indian context. As the Indian EV industry grows and more mainstream as well as new automakers enter the market, the availability of data across various sectors will increase. This

18. TATA, Mahindra & Mahindra, MG Motors India Pvt Ltd, Hyundai Motors India Ltd, Kia Motors India Ltd, Mercedes-Benz India Pvt Ltd and Toyota Kirloskar Motor Pvt Ltd.

will enhance the applicability and accuracy of the model for India. While current limitations exist, conducting research at this early stage of market development is immensely valuable. This research lays a crucial foundation for future analysis and strategy development, aligning with the evolving landscape of India's electric mobility sector.

The applicability of this model extends beyond the Indian economy and the four-wheeler market. It can be applied to different segments of the automobile market and to any nation aiming to implement a supply-side mandate and evaluate its potential impact on automakers. This model, or similar studies, can be particularly effective when detailed cross-sectional data is available over an extended period. This model will yield accurate results when applied in mature markets like China and the USA, where data spanning nearly two decades for specific variables required by this model is accessible. In such markets, extensive historical data allows for more precise predictions and robust analysis, ensuring that the model's outcomes are reliable and actionable.

Even in emerging markets with limited data over shorter periods, the model can still be valuable. If data on certain variables for EVs and ICE vehicles, such as cost, price, production, and the price of credits, is available, this model can provide a clear assessment of the impact and evaluate it against the intended effects of the supply-side production mandate. By leveraging available data on key variables, policymakers and stakeholders can gain a better understanding of the potential impacts of supply-side mandates, guiding strategic decisions and fostering a more informed approach to market development.

In conclusion, the versatility of this model makes it a powerful tool for analysing the implications of ZEV mandates across different contexts. Whether applied in well-established markets or emerging ones, the model's ability to adapt to varying data landscapes ensures its relevance and utility in shaping the future of electric mobility and automobile market strategies worldwide.

Data-based investigations like these are crucial for national policies and enable prompt course corrections. As India advances along a progressive path, maintaining a regimen of regular assessment and adaptation is essential. Further application, modifications and inquiry into this model would help policymakers, automakers and other stakeholders build strategies around production, investments and economic goals in the EV automobile ecosystem.

06 Key Learnings and Way Forward

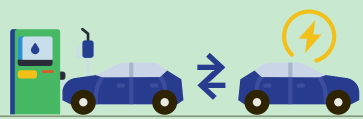
India is at a pivotal stage in its EV journey, aiming for ambitious penetration targets to establish itself as a key player in the EV ecosystem. Despite growing demand and ongoing innovations, there's a pressing need for technologically advanced yet cost-effective EVs, and to reduce import dependencies. The ZEV mandate emerges as a strategic tool. This report pioneers research into this underexplored area in India, offering a forward-thinking analysis of how ZEV can boost EV penetration, curb import reliance, and align with economic and environmental objectives. It covers a global perspective, assesses the current Indian EV landscape, and outlines the potential impact of the ZEV mandate. The report can serve as a vital resource for devising strategies for policymakers, automakers, government bodies, and researchers, to enhance India's EV ecosystem.

This report aims to provide a comprehensive overview of the Indian EV ecosystem, focusing on the potential implications of a ZEV mandate in India. Drawing lessons from successful ZEV implementations in major economies, the analysis emphasizes the importance of progressive policies across different tiers of technological advancement, the introduction of a credit system to incentivize EV adoption and the adjustment of tax incentives and subsidies as penetration levels increase. By continuously pushing for EV adoption on both national and international fronts, these measures can significantly impact the automotive industry's landscape.

An in-depth examination of the Indian automobile value chain reveals existing gaps, lopsided value addition across stakeholders and opportunities that India can leverage. While Indian manufacturers are predominantly engaged in assembly and partially in manufacturing, the report underscores the necessity for broader involvement across the value chain for holistic sectoral development. It is important that component manufacturers understand the increasing demand for specific components. Developing prowess in relatively less explored markets after-sales services such as charging, and recycling, can also help India gain a competitive advantage in the EV ecosystem.

Further, the report assesses the current stage of development in the Indian automobile sector, including its readiness for a potential mandate, which is crucial for strategic planning. The report introduces a mathematical model designed to estimate the potential ramifications of a ZEV mandate on India's automobile ecosystem. This model, with its broad applicability across economies and industry segments, facilitates the assessment of supply-side mandates' impacts, providing valuable insights for policymakers, industry stakeholders, and researchers alike.

Transitioning in the automobile sector will require careful planning, collaboration, and policy support to mitigate disruptions. The insights from this report can be useful in ensuring a smooth transition that achieves the economic and environmental targets.



The following are the key takeaways from the report:

01 Balance of Demand and Supply Side Policies.

In the past decade, the Government has implemented significant measures to bolster EV penetration, with a primary emphasis on stimulating consumer demand. These policies align with the best practices globally. These policies, however, are predominantly dependent on subsidies and monetary incentives. Though this is a crucial initial step, a study of the successful EV economies like China, the US, and Norway indicates that such practices are unsustainable for the Government and should be phased out as the EV penetration increases. The Indian Government has followed suit by phasing out the FAME Policy. Additionally, these policies do not directly address critical aspects such as manufacturing costs, technology, or innovation, which are essential for cultivating a robust ecosystem. While these policies are important for ensuring positively dynamic demand conditions, it is equally imperative to adopt supply-side policies that reduce production costs for EV manufacturers. Ensuring a balance between policies that incentivize consumers and those that support manufacturers at all levels is crucial for sustainable growth and development in the industry.

A balanced approach, integrating both demand and supply-side policies, is vital. Customized supply-side strategies for each segment of the automotive value chain, spanning from raw material extraction to after-sales services, play a pivotal role. Introducing a ZEV mandate can act as a significant supply-side policy, compelling not just automakers but all stakeholders to ramp up their production capabilities. This surge in production, alongside the development of crucial value chain links currently lacking in the Indian ecosystem, will gradually take shape. Such concerted efforts, incentivizing and engaging all participants, are essential for establishing a robust domestic supply chain. This approach streamlines both forward and backward linkages, ultimately reducing reliance on imports.

02 Reduction in Total Cost of Ownership to Increase EV Penetration.

Although the total cost of ownership of EVs is approximately 25% lower than that of ICE vehicles, the high initial upfront cost remains a significant barrier for consumers. Overcoming this barrier necessitates a focus on producing EVs within a price range accessible to a broader population. The implementation of a ZEV mandate plays a pivotal role in achieving this objective.

The ZEV mandate acts as a catalyst by obligating manufacturers to scale up production, thereby driving economies of scale that can lead to reduced production costs.

This, in turn, enables the development of affordable and efficient EV models that align with market demand. Consequently, the pressure on EV costs facilitates greater market penetration, initiating a positive cycle of adoption that benefits not only manufacturers and consumers but also contributes to the nation's economic and environmental sustainability goals.

03 Synergizing Stakeholder Efforts for Efficient EV Development.

EV is a disruption to the automobile industry and the ZEV mandate will be an intervention that will lead to significant supply chains in the Indian automotive sector. To successfully navigate through the EV transition, collaborative effort from all stakeholders is essential. A proactive approach from automakers, meticulously crafted government policies, strategic incentives, and the removal of impediments on both the demand and supply fronts can propel India towards the realization of its ambitious environmental and mobilization targets.

The Government's consistent efforts and policy frameworks not only focus on promoting EV manufacturing but also aim at nurturing an entire EV ecosystem. Private players must play a crucial role by heavily investing in research, development, and technological innovation. Aligning these investments with governmental policies will not only make automobiles cost-competitive but also technologically advanced. This strategic alignment is essential for Indian manufacturers to gain a competitive edge in the global EV market landscape.

04 Reduction of Infrastructural and Financial Barriers to Adopt EVs.

A fundamental pillar of these transition strategies involves long-term strategic planning, fostering a consistent and robust approach to ZEV implementation while ensuring market readiness. The efficacy of financial incentives, such as tax breaks and credit systems, has been demonstrated in leading nations like the United States and Norway. India could leverage similar mechanisms to incentivize both consumers and manufacturers, fostering a seamless transition to EVs. Taking cues from countries like China and the European Union, prioritising infrastructure development is pivotal. As EV adoption increases, the EV-per-charger ratio is a critical metric for assessing charging network adequacy. Countries like China, Korea, and the Netherlands have maintained fewer than ten EVs per charger in recent years, while India has 135 EVs (PVs and 2Ws) and 86 EVs per charging station for 3Ws. Allocating funding and legislative support for the expansion of EV charging networks will play a crucial role in shaping India's EV landscape.

05 Strengthening CAFE Regulations and Credit Systems.

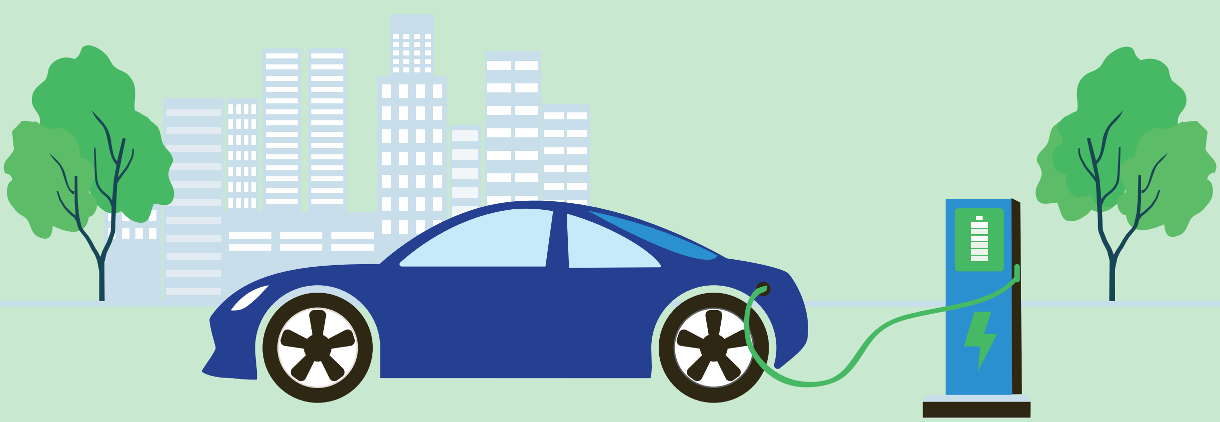
India's automotive industry operates under Corporate Average Fuel Efficiency (CAFE) norms that include provisions for super credits, albeit with limitations in their current implementation. The existing credit system lacks clear guidelines regarding their utilization, rollover mechanisms, trading possibilities, and penalties.

As India aims for 30% EV penetration by 2030, these norms can play a vital role in incentivising automakers to produce EVs. However, the current norms are inadequate for this motive. The current norms allow manufacturers to fulfil minimum credit requirements without manufacturing EVs, despite the higher credit weights for BEV, PHEV and HEV.

Stricter CAFE norms and credit regulations, with stringent penalty and reward conditions, requiring a minimum share of EV production would compel manufacturers to prioritize EV manufacturing.

Moreover, integrating mechanisms like trading credits or imposing penalties could further incentivize EV production, potentially creating a competitive advantage for manufacturers embracing EV technologies. This proposed strategy not only aligns with global trends towards sustainable transportation but also acts as a preparatory step towards a ZEV mandate. By gradually increasing the emphasis on EV production within the existing credit framework, the automotive industry can smoothly transition towards higher EV volumes annually, thus contributing significantly to India's sustainable mobility goals.

This report is one of the first attempts to explore the possibility and applicability of the ZEV mandate on the four-wheelers in India. The insights gained from this report contribute to a growing body of knowledge that can inform policy refinements and strategic decisions moving forward. India can embrace a strategy of incremental policy adjustments, ensuring a sustainable and well-paced shift towards ZEV that aligns with the nation's technological and economic evolution. This report aims to help stakeholders in India navigate the complexities of transitioning to ZEV while accommodating domestic needs and capacities by addressing the unique challenges and opportunities within its domestic landscape. This will position India as a proactive contributor to the global movement towards sustainable mobility.

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Appendix

Section 1- Value Chain Analysis based on ProwessIQ data.

Data was extracted from the ProwessIQ database, based on NIC codes that are required in the automobile industry. The following tables detail the data and formula used for value chain analysis.

Table- 1 Formula Used for Value Addition Calculations

Formula for Value Added	Total Income- (Total Expenses (Intermediate costs) + Change in stock)
Components of Total Expenses	Raw Material
	Stores, spares and tools consumed
	packaging and packing expenses
	Purchase of finished goods
	Power, Fuel and water charges
	Compensation to employees
	Indirect Taxes

Formula for Value Added	Total Income- (Total Expenses (Intermediate costs) + Change in stock)
Components of Total Expenses	Royalties, technical know-how fees
	Rent and Lease Rent
	Repairs and Maintenance
	Insurance premium paid
	Outsourced manufacturing Jobs
	Outsourced professional Jobs
	Non-executive directors' fees
	Selling and Distribution expenses
	Travel Expenses

Table- 2 NIC Codes used in Value Chain Analysis

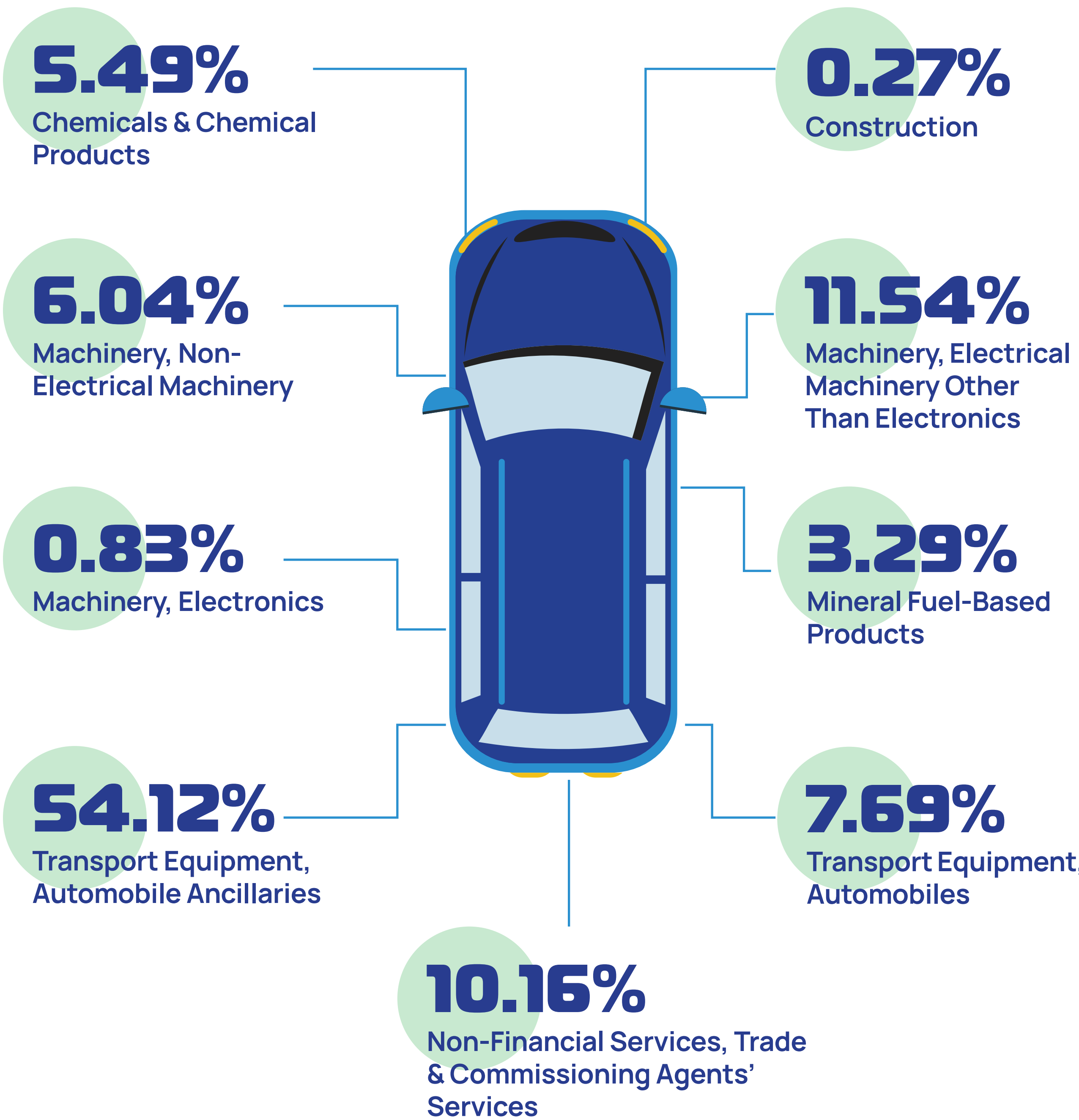
NIC Codes	Description
6101	Offshore extraction of crude petroleum
6102	On shore extraction of crude petroleum
7100	Mining of iron ores
729	mining of other non-ferrous metal ores
19201	Production of liquid and gaseous fuels, illuminating oils, lubricating oils or greases or other products from crude petroleum or bituminous minerals

NIC Codes	Description
22111	Manufacture of rubber tyres and tubes for motor vehicles, motorcycles, scooters, three-wheelers, tractors and aircraft
22113	Re-treading of tyres; replacing or rebuilding of tread on used pneumatic tyres
22119	Manufacture of rubber tyres and tubes N.E.C.
22192	Manufacture of rubber conveyor or transmission belts or belting
26105	Manufacture of display components (plasma, polymer, LCD, LED)
27320	Manufacture of other electronic and electric wires and cables (insulated wire and cable made of steel, copper, aluminium)
28120	Manufacture of fluid power equipment
28140	Manufacture of bearings, gears, gearing and driving elements
28192	Manufacture of air-conditioning machines, including motor vehicles air-conditioners
29101	Manufacture of passenger cars
29102	Manufacture of commercial vehicles such as vans, lorries, over-the-road tractors for semi-trailers etc.
29103	Manufacture of chassis fitted with engines for the motor vehicles included in this class
29104	Manufacture of motor vehicle engines
29109	Manufacture of motor vehicles N.E.C.
29201	Manufacture of bodies, including cabs for motor vehicles
29209	Manufacture of other attachments to motor vehicles N.E.C.
29301	Manufacture of diverse parts and accessories for motor vehicles sucs as brakes, gearboxes, axles, road wheels, suspension shock absorbers, radiators, silencers, exhaust pipes, catalysers, clutches, steering wheels, steering columns and steering boxes etc.

NIC Codes	Description
29302	Manufacture of parts and accessories of bodies for motor vehicles such as safety belts, airbags, doors, bumpers
29303	Manufacture of car seats
29304	Manufacture of motor vehicle electrical equipment, such as generators, alternators, spark plugs, ignition wiring harnesses, power window and door systems, assembly of purchased gauges into instrument panels, voltage regulators, etc.
30911	Manufacture of motorcycles, scooters, mopeds etc. and their engine
30912	Manufacture of three-wheelers and their engine
30913	Manufacture of parts and accessories of three wheelers and motorcycles including side cars
45101	Wholesale and retail sale of new vehicles (passenger motor vehicles, ambulances, minibuses, jeeps, trucks, trailers and semi-trailers)
45102	Wholesale and retail sale of used motor vehicles
45200	Maintenance and repair of motor vehicles
45300	Sale of motor vehicle parts and accessories
45401	Wholesale or retail sale of new motorcycles, mopeds, scooters and three wheelers
45402	Wholesale or retail sale of parts and accessories of motorcycles, mopeds, scooters and three wheelers
45403	Maintenance and repair of motorcycles, mopeds, scooters and three wheelers
47300	Retail sale of automotive fuel in specialized stores [includes the activity of petrol filling stations.

Source- Ministry of Statistics and Programme Implementations

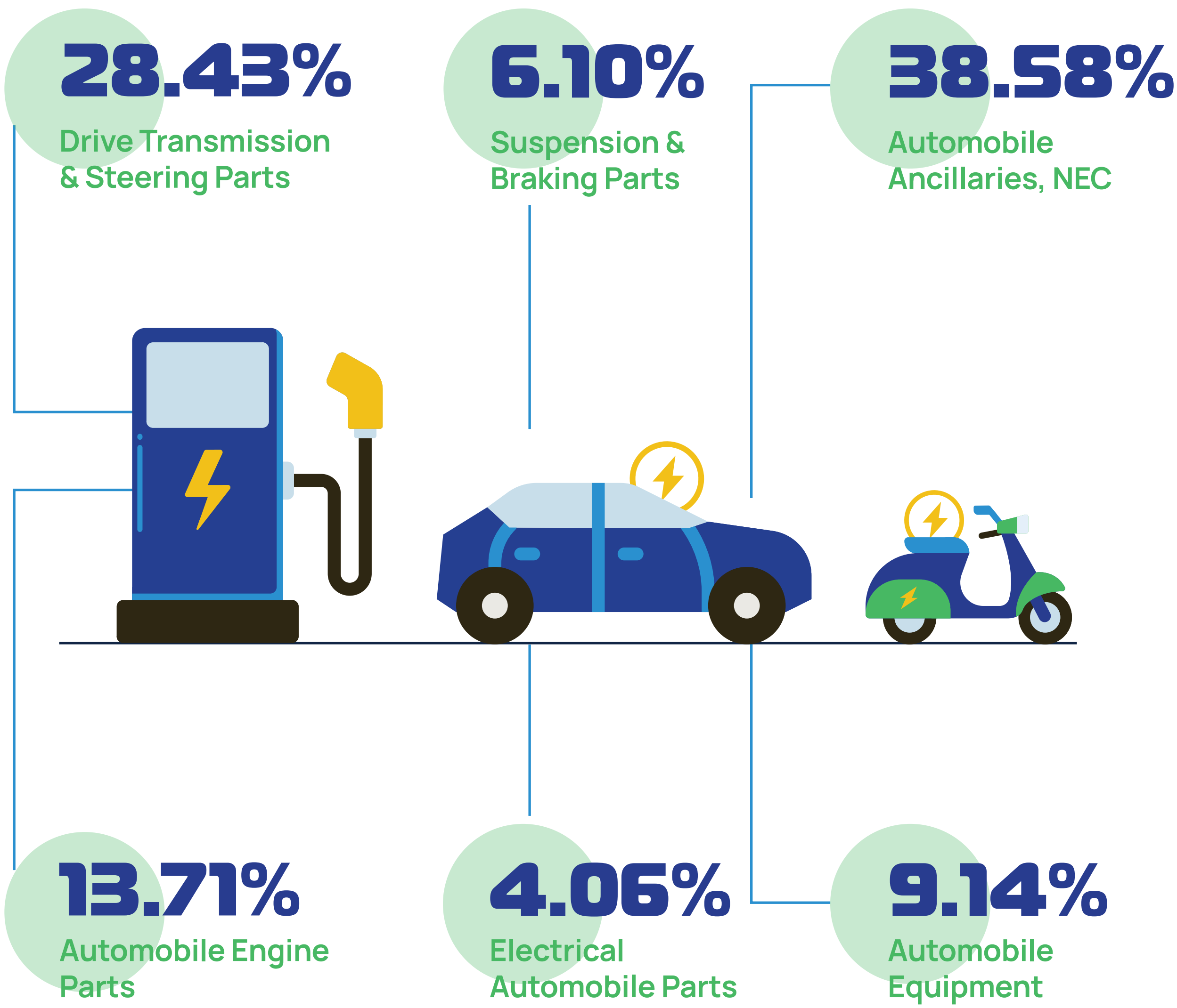
Figure-1 Percentage of Stakeholders in the Indian Automobile Value Chain



Source- Authors' Analysis based on ProwessIQ Data Base

Stakeholders involved in transport equipment (automobile ancillaries) can be further broken down. These components comprise of Tier 2 and Tier 3 manufacturers that are potentially most vulnerable to the transition from ICE to EV.

Figure-2 Percentage of Stakeholders in Transport Equipment



Source - Authors' Analysis based on ProwessIQ Data Base

Section 2- Total Cost of Ownership Analysis

There has been considerable literature evaluating the TCO for various powertrain systems such as ICE, EV, PHEV, HEV, BEV and their variants, across locations and spanning over different periods. Early studies, provided in-depth TCO assessments for vehicles like hybrids and electric cars in developed nations, considering factors beyond initial costs, such as depreciation and fuel efficiency (Palmer, Tate, Zia, & Nelthorp, 2018). Further, research in this domain has been extended to electric buses, wheelers and three-wheelers, adding infrastructure and environmental costs into the equation, suggesting their viability with mass production (Kumar & Subrata, 2020; Orhan & Nakir, 2018).

More recent studies (Deloitte, 2021) analysed electric mobility in Southeast Asia, focusing on TCO related to upfront costs, taxes, and service expenses. This study highlighted the influence of cost proportions on EV adoption and the role of energy prices. The IIT Kanpur study (Agarwal K. A., 2023) used the World Resources Institute India's TCO evaluator to examine life cycle emissions and TCO for various vehicles in India, suggesting that HEVs with e-fuels could be economically viable with appropriate subsidies.

These TCO studies underline the importance of factoring in diverse costs and market-specific conditions. However, the literature often overlooks policy influences and cost incentives, which are crucial for understanding consumer preferences and encouraging the adoption of innovations like EVs, particularly in the Indian context. Incentives directly affect TCO and are key to integrating new technologies within the automotive sector.

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a) Method for TCO analysis

Upon examination, the key components of the total cost of ownership (TCO) formula include purchasing cost, resale price, taxes, energy costs, and maintenance costs. Considering these main components and insights literature, the following formula has been formulated

Formula

TCO = Vehicle Cost + Energy Costs + Maintenance Costs

Where,
Vehicle cost = On-road price (Inclusive of one-time charges (e.g. Taxes like GST, Road Tax, TCS charges and Insurance Costs) – Resale Value
Energy costs = Petrol, diesel, charging costs
Maintenance cost = Service Charges and Potential Battery Replacement costs in case of EV.

All expenses are standardized for a specific region, taking Delhi as a reference due to cost variations across different regions of India. For two-wheelers, a period of 10 years, with an annual distance of 10,000 km is considered based on average life and usage in the current market. For four-wheelers, the evaluation considers 5 years, and an annual distance of 15000 km is considered, based on the average usage of four-wheelers in India based on market analysis. All the costs are base level, i.e. minimum price that will be required. Energy cost, annual kilometers and life of the vehicle are subjective to consumers' usage. The market is subject to innovation, and inflation and is subject to change according to socio-economic conditions. The TCO calculations aim to illustrate the cost-effectiveness of vehicles and their variants in business-as-usual conditions. An increase in the efficiency of EVs can be expected with the rise of innovation.

The evaluation of four-wheelers is done in 3 different scenarios:

i) Scenario I- 5% GST and tax exemptions (Current Scenario in India)

ii) Scenario II- No GST and road tax for EVs (Incorporating tax exemptions prevalent in major economies such as China)

iii) Scenario III- 40% subsidy on purchase price and no GST & road tax (Ideal Tax cuts required to produce cars in consumers purchasing power capacities)

For the analysis, the top-selling vehicles in both the two-wheeler and four-wheeler markets have been considered. For fairness in evaluating four-wheelers, variants of the same car (TATA Nexon Creative Plus) have been considered.
As equivalent variants are unavailable in the two-wheeler market, we opted for two different models, the best-selling petrol (Activa 6G) and electric (Ola S1 Pro (2nd Gen)) options.
The e-AMRIT website served as a resource for calculating the cost per kilometer for EVs. Since EVs are relatively new in the market, there is a lack of data on the resale values of the latest EV models. Hence, the resale value of four-wheeler EVs has been estimated based on diesel cars and based on the resale value of previous models in the case of two-wheelers.

Table- 3 TCO Calculations for Two Wheelers.

Vehicle	Model	Vehicle Cost		Energy Cost	Maintenance Cost	TCO
		Purchase Cost (₹)	Resale Value (₹)	Cost Per Km (₹)	Cost Per Year (₹)	Usage Period 10 years, at 12000 km per year
Two Wheelers	Activa 6G	₹89,843	₹62,300	₹1.75	₹2,160	₹2,31,600.00
	Ola S1 Pro (2nd Gen)	₹1,37,110	₹1,10,000	₹0.13	₹87,928	₹1,03,528.00
		₹159378 (cost) - ₹22268 (subsidy)				

Source- Ministry of Statistics and Programme Implementations

Table- 4 TCO Calculations for Four-Wheeler Passenger Cars.

Vehicle	Model	Vehicle Cost		Energy Cost	Maintenance Cost	TCO
Four-Wheeler		Purchase Cost (₹)	Resale value (₹)	Cost per km (₹)	Cost per year (₹)	Usage Period 5 years at 15,000 km per year
Scenario I- Current Scenario (5% GST and tax exemptions)	Tata Nexon Creative Plus Petrol	13,32,842	4,53,482.5	5.54	4856.2	13,19,140
	Tata Nexon Creative Plus Diesel	15,40,213	4,06,198.4	3.8	6271.6	14,50,372
	Tata Nexon Creative Plus EV	15,43,905	5,61,523	0.8	4092.2	10,62,843
Scenario II- (No GST and road tax for EVs)	Tata Nexon Creative Plus EV	14,57,960	5,61,523	0.8	4092.2	9,76,898
Scenario III- (40% subsidy on purchase price and no GST & road tax.)	Tata Nexon Creative Plus EV	8,96,436.8	3,36,913.8	0.8	4092.2	6,39,984

Source- Authors calculation based on data from mycarhelpline.com, cardekho.com, 91-cdn.com.

In the case of two-wheelers, the subsidies due to FAME I and II have sufficed to reduce the TCO and EVs have an evident advantage and have a huge cost-efficiency advantage.

However, in the four-wheeler segment, variants, and a large number of components the evaluation becomes complicated. Scenario 1 considers the current situation. Currently, EV cars fall in the 5% GST tax slab and 11 of the major states in India (Andhra Pradesh, Bihar, Delhi, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Tamil Nadu, Telangana, Uttar Pradesh and Uttarakhand) have exempted or subsidised the road tax. As this analysis is done based on Delhi, road tax is taken as per the region.

In the second scenario, we explore the impact on the initial cost and total cost of ownership (TCO) by envisioning a scenario where all taxes, akin to China's elimination of the purchase tax, are removed. Notably, the TCO of EVs is lower in both scenarios. However, in the first scenario, should a battery exchange become necessary due to wear and tear, the TCO experiences a significant increase. Despite these variations, the upfront cost remains prohibitively high for the majority of Indian consumers in both scenarios, a challenge that we address in the subsequent scenario.

Moving on to the third scenario, it envisions the optimal conditions for EV adoption. An analysis of the latest available sales data (refer to the section titled India's Automobile Industry Value Chain) consumers prefer passenger vehicles in the INR 6-10 lakh range. Scenario 3 indicates that a subsidy of approximately 30%-40% in price is needed to align with the initial cost within consumers' financial reach. However, such a significant subsidy poses financial challenges for both the government and producers, potentially hindering production and innovation in the EV sector. Therefore, the industry needs to focus on reducing costs from the supply side by increasing production efficiency.

Section 3- Details of the Model to evaluate impact of ZEV mandates in India.

The model is formulated for four-wheelers and two-wheelers separately.

a) Formulation of the Model: Four-Wheeler Market in India

In this research model, the focus lies majorly on the four-wheeler manufacturing industry. The primary reason for focusing the research on the specific vehicle segment is due to the notably low penetration of ZEVs in this vehicle segment compared to other segments such as two-wheelers or commercial vehicles. India's ZEV penetration in the four-wheeler passenger vehicle segment stands at a mere 1.64%, far below the government's ambitious target of achieving a 30% market share in ZEVs by 2030. To delve deeper, the model categorizes vehicle manufacturers into two distinct groups based on their current production composition and diversification.

Category 1

Firstly, Category 1 encompasses companies engaged in the production of both ZEVs and internal combustion engine vehicles (ICEs). This group includes TATA Motors Passenger Vehicles, Morris Garages Motor India, Hyundai Motors India, Kia Motors India, Mahindra and Mahindra Limited, and Mercedes Benz India. On average, these companies produced 6,292 ZEVs and a substantial 245,347 ICEs in the year 2022-23. Notably, TATA Motors Passenger Vehicle Limited boasted the highest ZEV production at 31,723 units, albeit constituting only 7% of its total output. MG Motors led in ZEV proportion, with ZEVs comprising 10% of its total production. Although these companies clearly outperform the segment average, they fall short of the mandate requirement proposed in the model. To comply with the mandate, they will need to significantly scale up their existing ZEV-focused infrastructure. As pioneers of ZEV vehicle production in the country, they have a remarkable opportunity to become key suppliers of ZEV credits in the credit market post-mandate implementation.

Category 2

On the other hand, Category 2 comprises automakers solely engaged in ICE production as of 2022-23, without any ZEV sales. This group includes Maruti Suzuki India, Renault India, Honda Cars India Ltd., Skoda Auto Volkswagen India Pvt. Ltd., and Fiat India. With an average ICE production of 245,307 units, these companies face significant challenges upon the mandate's introduction, given their current absence of ZEV production. Meeting the proposed ZEV mandate will necessitate substantial investment in R&D and capital infrastructure for such manufacturers in the near future.

i) Assumptions of the model

1. The model simplifies the market dynamics by considering only two key players: Company 1 and Company 2.

2. Company 1 represents the more diversified Category 1 automobile manufacturers, encompassing a range of companies involved in both ZEV and ICE vehicle production. Meanwhile, Company 2 serves as a proxy for Category 2 manufacturers, which solely focus on ICE vehicle production without any current involvement in the ZEV market.

3. The model assumes a simplified market scenario where only one type of ZEV and one type of ICE vehicle are produced by manufacturers in the Indian market.

4. Vehicle prices are considered exogenous in the model, meaning they are determined externally and do not directly affect the interactions between manufacturers. The price of ZEV vehicles is based on the TATA Nexon EV, while the price of ICE vehicles is derived from the average prices of TATA Nexon's Petrol and Diesel variants.

5. ZEV credits earned by manufacturers cannot be carried forward to subsequent years in the model. This assumption reflects the regulatory requirement that credits must be utilized within the same financial year they are earned, preventing manufacturers from accumulating credits over time.

6. The model prohibits manufacturers from borrowing credits against future ZEV production to meet current targets. This restriction ensures that manufacturers cannot rely on hypothetical future production to fulfil their current obligations, promoting transparency and accountability in compliance with the ZEV mandate.

7. Each company in the model is assumed to be a rational player in the market, seeking to maximize its profit within the constraints of the ZEV mandate and market conditions.

8. The model does not differentiate between sales and production activities within the same time period. This simplifying assumption enables a straightforward assessment of the relationship between production levels, sales volumes, and profitability for manufacturers under the ZEV mandate.

9. The time horizon for the model is limited to one year, allowing for a focused analysis of the short-term implications of the ZEV mandate on manufacturers' operations, financial performance, and compliance strategies.

ii) The Objective Function

The objective function of each firm is equal to its total profit earned by the firm from the sale of ZEVs, ICEs and the trade of ZEV credits. The Profit of the firm i is given by –

$$\pi_i = \pi_{zevi} + \pi_{ICE_i} + \pi_{(trade\ of\ creditsi)} \quad \ldots\ldots\ldots \quad (1)$$

here 'i' takes values 1 and 2 representing companies 1 and 2.

π_i = Total profit for the firm 'i'

π_{zevi} =Profit of firm 'i' from the production and sale of Zero Emission Vehicles

π_{ICEi} =Profit of firm 'i' from the production and sale of Internal Combustion Engine Vehicles

$\pi_{trade\ of\ creditsi}$ =Profit for firm 'i' from the sale and purchase of ZEV credits

The individual equations for the components of the total profit are given below-

$$\pi_{Zevi} = P_{zev} * x_i - (c_i (x_i)^3 + d_i (x_i)^2 + e_i (x_i)) - FC_{zevi} \quad \ldots\ldots\ldots (2)$$

where,

P_{zev} refers to the market price of the zero-emission vehicle in the market.

x_i denotes the quantity of zero-emission vehicles produced by company 'i' in the current year.

c_i, d_i, e_i are the coefficients of the cubic cost function for the firm

FC_{zevi} is the fixed cost beared by firm i for the production of zero emission vehicles.

$$\pi_{ICE} = (P_{ICE} - MC_{ICE}) * y_i - FC_{ICE_i} \quad \ldots\ldots\ldots \quad (3)$$

where,

P_{ICE} is the market price of the Internal Combustion Engine Vehicle

MC_{ICE} is the marginal cost of production of a unit of ICE vehicle.

y_i is the production of internal combustion vehicles by the automaker 'i' in the current period.

FC_{ICEi_i} is the fixed cost beared by firm 'i' for the production of ICE vehicles.

$$\pi_{(trade\ from\ credits)} = P_{(zev\ credits)} * (qs_i - qp_i) \quad \ldots\ldots\ldots \quad (4)$$

where,

$P_{(zev\ credits)}$ is the price at which ZEV credits are being traded in the ZEV credit market.

qs_i refers to the number of ZEV credits sold by company 'i' in the current financial year.

qp_i refers to the number of ZEV credits purchased by company 'i' in the current financial year.

iii) Optimisation Constraints in the model

The optimization exercise of the firm encounters various constraints, particularly concerning the significant investment required to increase production levels, especially for ZEVs. Given the strategic nature of transitioning to a substantial proportion of ZEVs, there are limits on the extent to which a manufacturer can scale up its production of both ICE and ZEVs.

We assume that each company can produce a maximum of 200,000 ZEVs in the current year of the model. This assumption is reasonable considering that the companies represented by Company 1 only produced 6,292 ZEV vehicles on average in the year 2022-23, and those in Category 2 did not produce any ZEVs during the same period.

Similarly, companies in the model are constrained to increase their production of ICE vehicles by a maximum of four (4) times compared to the previous period due to constraints of increasing investment and production volumes at a very large scale.

These constraints are expressed in equations 5 and 6 within the model.

$$x_i \leq 2{,}00{,}000 \quad \ldots\ldots (5)$$

$$y_i \leq 4 * (OQ_{ICE_i}) \quad \ldots\ldots (6)$$

where, OQ_{ICE_i} refers to the production of ICEs by company 'i' in the year 2022-23.

Additionally, the implementation of the mandate necessitates strategic decisions regarding ICE vehicle production, potentially leading to reductions in ICE production by the manufacturer. The model assumes that ICE production in the current year cannot fall below 10% of the production in the previous year for both companies. This constraint is represented by equation 7.

$$y_i \geq 0.10 * (OQ_{ICE_i}) \quad \ldots\ldots (7)$$

To prevent firms from engaging in arbitrage within the market, constraints are imposed on the quantity of credits purchased (qpi) and the quantity of credits sold (qsi) by each company.

Equation 8 establishes a constraint that prohibits firms from purchasing credits unless they fall short of their ZEV credit target. This restriction ensures that companies only resort to buying credits when necessary to meet their obligations under the mandate, discouraging speculative behaviour in the credit market.

$$qp_i \leq Max \{ (0.3 * 2 * (x_i + y_i) - 2 * x_i), 0) \} \quad \ldots\ldots (8)$$

Similarly, equation 9 imposes a constraint that prevents firms from selling credits in the market unless their earned credits exceed their target level. By enforcing this rule, companies are compelled to fulfil their credit targets before considering selling excess credits, thereby preventing manipulation of the credit market for short-term gain.

$$qs_i \leq Max\{(2 * x_i - 0.3 * 2 * (x_i + y_i)), 0\} \quad \text{..................(9)}$$

These constraints serve to maintain the integrity and stability of the credit market by restraining companies from engaging in unnecessary buying or selling of credits solely for for-profit motives. By promoting responsible and strategic utilization of credits, the regulatory framework aims to foster a fair and efficient marketplace conducive to achieving the overarching goals of the ZEV mandate.

Within the model's framework, one constraint stands out as paramount: the fulfilment of the mandate by all automakers in the market. As specified in equation 10, this constraint dictates that the total credits accrued by each automaker from ZEV production and trading in the ZEV credits market must exceed their target level of ZEV credits, under penalty of non-compliance.

$$2 * x_i + qp_i - qs_i - 2 * 0.3 * (x_i + y_i) \geq 0 \quad \text{................. (10)}$$

The model's equilibrium hinges on a fundamental constraint outlined in equation 11 serving as the sole equality constraint within the framework. This equation asserts that the aggregate demand for ZEV credits within the market must precisely match the total supply of credits available, ensuring that the credit market is in equilibrium.

$$\Sigma qs_i = \Sigma qp_i \quad \text{.. (11)}$$

iv) Estimation of the parameters of the model

The parameters in the model are derived from extensive research on the Indian four-wheeler vehicle market. The price of a ZEV is set at Rs 15,43,905, aligned with total cost of ownership (TCO) calculations. Conversely, an ICE is priced at Rs 14,36,528. The marginal cost of producing an ICE is assumed to be 60% of its market price, equating to Rs 8,61,917. Historical production data for each company in ZEVs and ICEs is sourced from the Vahaan dashboard by the Ministry of Road Transport and Highways, providing sales numbers for various vehicle segments by automakers in different financial years. Due to the availability of only sales data, the distinction between sales and production is not made.

For historical production, the average production of vehicles of each type by companies in each group is taken. The selection of companies for analysis is based on market share among major automakers and data availability in the Prowess database, used for estimating cost functions. Cost functions, assumed to be cubic, are derived from the total costs of automakers in the two groups from 2017-18 to 2022-23. However, bifurcation of costs based on vehicle types is not feasible due to data limitations. ZEV-specific cost functions for each automaker couldn't be derived due to a lack of ZEV-specific cost data.

Fixed costs for manufacturing ICEs are based on Company 2's cost function, representing a pure ICE manufacturer in the market.

c) Two-Wheeler Market

The mathematical model used previously will be replicated for the two-wheeler sector. The classification of manufacturers in the two-wheeler market is determined by the specific type of vehicles they make. The model presupposes that the ZEV requirement for the producers of two-wheelers is established at 70% of their total production, aligning with the nation's objective of achieving ZEVs by 2030. Therefore, the desired level of ZEV credits for two-wheelers is determined by:

Target ZEV Credits = 2 x 0.7 x (Total production of vehicles by the firm).

The allocation of credits for two-wheeler ZEVs remains comparable to that of producers of four-wheeler vehicles. Credit trading is permitted. The regulations pertaining to banking and the utilization of credits bear a resemblance to the framework established for four-wheeler vehicles. The optimization problem and constraints remain unchanged from the four-wheeler model. The distinction between the two models rests in the classification of companies included in each model.

The classification of manufacturers in the two-wheeler market is as follows:

Category 1

consists of manufacturers who exclusively produce zero-emission vehicles on the market. The companies listed in the initial category are Ather Energy and Hero Electric Vehicles Pvt. Ltd. The limited inclusion of only two manufacturers in this category is a result of the absence of data pertaining to additional manufacturers of pure ZEVs. The mean production of ZEVs for these enterprises during the financial year 2022–23 was 82,777. Since these enterprises exclusively produce electric vehicles, they will have no difficulty meeting the mandate targets in the future.

Category 2

refers to manufacturers exclusively involved in the production of internal combustion engine (ICE) automobiles. The firms listed in the second category are Hero Motocorp Ltd., Honda Motorcycle and Scooter India Pvt. Ltd., TVS Motor Company Ltd., and Bajaj Auto Ltd. The average production of internal combustion engine (ICE) vehicles for manufacturers in this category is 33,24,633 units. Given the significant magnitude of non-ZEV manufacturing by these enterprises, the implementation of the rule would necessitate substantial investments from manufacturers in the production of ZEV vehicles.

The forthcoming phase of our research will involve the utilization of models designed to simulate the impact of implementing a ZEV mandate within the Indian automotive market across two distinct vehicle segments. We will incorporate data sourced from relevant Indian scenarios available in the public domain to enhance the robustness of our analysis. Through this endeavor, we aim to not only discern the shifts in production dynamics for these vehicle categories following the implementation of the ZEV mandate but also to ascertain the resultant alterations in automakers' profitability under a tradable credit-based ZEV mandate policy. Additionally, our investigation seeks to evaluate the efficacy of such a policy in fostering the proliferation of ZEVs within the Indian market landscape in the foreseeable future.

08

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