REPORT

NRDC

AUGUST 2025

FUELING ZEV TRANSITION

Global Review of Supply-Side Regulations and India's Opportunity

ABOUT

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Abbreviations

ACC	Advanced Clean Cars
ARAI	Automotive Research Association of India
BEE	Bureau of Energy Efficiency
BEV	Battery Electric Vehicle
BS	Bharat Stage Standards
CAFC	Corporate Average Fuel Consumption
CAFE	Corporate Average Fuel Economy
CAGR	Compound Annual Growth Rate
CARB	California Air Resources Board
CEM	Clean Energy Ministerial
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Carbon dioxide-equivalent
CoP	Conformity of Production
EAER	Equivalent All Electric Range
ELV	End-of-Life Vehicles
EMPS	Electric Mobility Promotion Scheme
EPA	Environmental Protection Agency
EU	European Union
EUR	Euro
EV	Electric Vehicle
EVI	Electric Vehicle Initiative
FAME	Faster Adoption and Manufacturing of (Hybrid) and Electric Vehicles
FCEV	Fuel Cell Electric Vehicles
FY	Financial Year
GARC	Global Automotive Research Centre
GBP	Great British Pound
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GVW	Gross Vehicle Weight
HC+NOx	Hydrocarbons + Nitrogen Oxides
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicles
HSD	High-Speed Diesel
ICE	Internal Combustion Engine
IEA	International Energy Agency
INR	Indian Rupee
IRA	Inflation Reduction Act
LDT	Light duty trucks
LDV	Light-Duty Vehicle
MIIT	Ministry of Industry and Information Technology
MMT	Million Metric Tons
MY	Model Year
NEMMP	National Electric Mobility Mission Plan
NEV	New-Energy Vehicle
NMOG+NOx	Non-Methane Organic Gases Plus Oxides of Nitrogen
NOx	Nitrogen Oxides
OEM	Original Equipment Manufacturer
OMC	Oil Marketing Companies
PCS	Public Charging Stations
PHEV	Plug-In Hybrid Electric Vehicle
PM	Particulate Matter
R&D	Research and Development
RUC	Road Usage Charges
SO_2	Sulphur Dioxide
SSR	Supply-Side Regulations
STU	State Transport Undertakings
SUV	Sport Utility Vehicle
TCO	Total Cost of Ownership
TZEV	Transitional Zero Emission Vehicle
UK	United Kingdom
US	United States
USD	United States Dollar
VAT	Value Added Tax
VVMP	Voluntary Vehicle Fleet Modernization Program
WLTP	Worldwide Harmonised Light Vehicles Test Procedure
ZEV	Zero Emission Vehicles
ZLEV	Zero- and Low-Emission Vehicles

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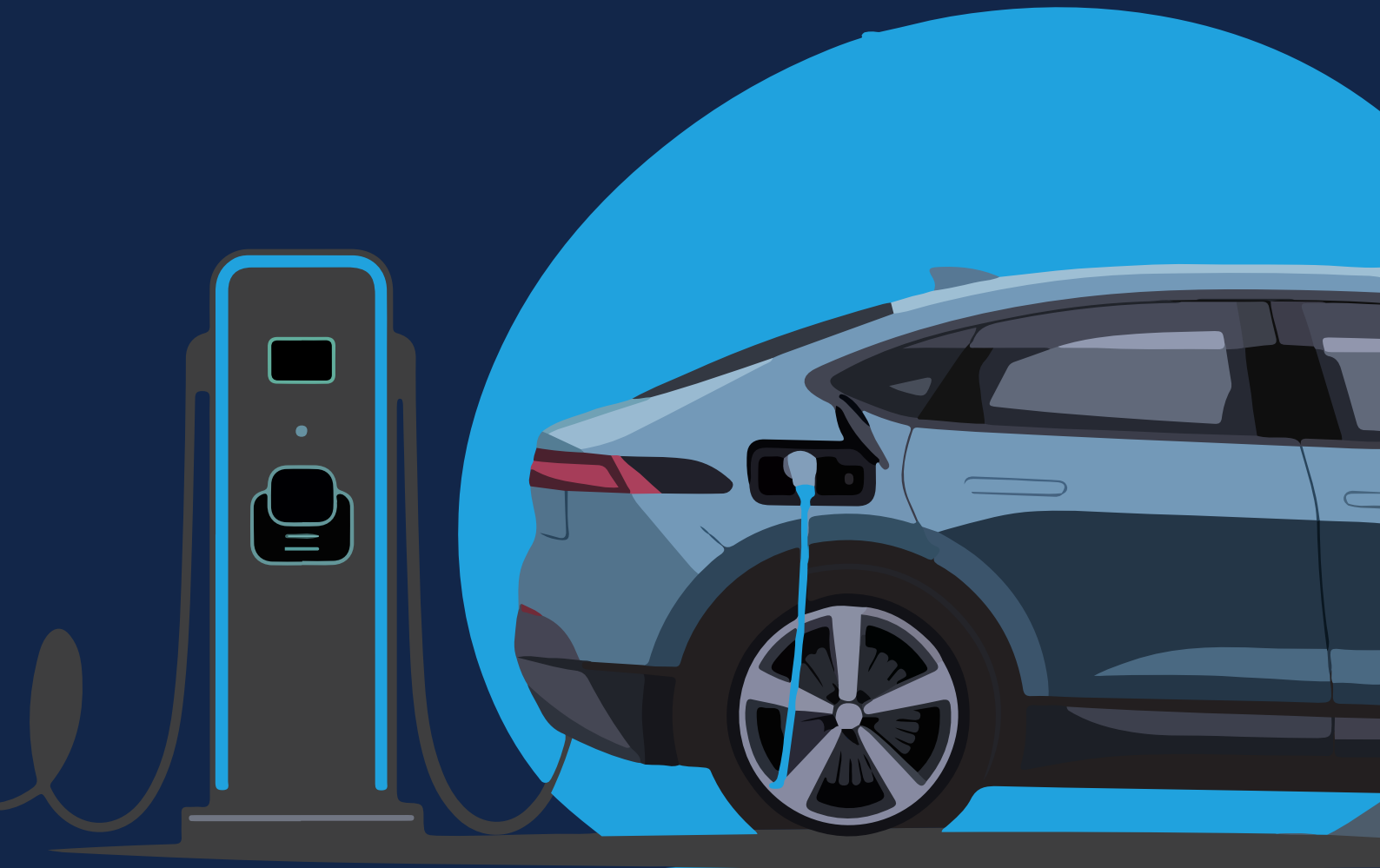
Source: Freepik.com

Executive Summary

The transport sector is among the largest and fastest-growing consumer of fossil fuels of any sector. It accounts for nearly 30% of global CO_2 emissions from end-use sectors.[1] Nearly 90% of the carbon dioxide (CO_2) emissions from transportation in India come from the road sector.[2] Vehicle ownership in the country has more than doubled over the past decade, growing from approximately 159 million in 2012 to over 354 million in 2022.[3] Countries worldwide are striving to decarbonize road transport, particularly by promoting zero-emission vehicles (ZEVs). India is no exception, with transportation emerging as a critical focus area for climate action.



As India seeks to meet a growing demand for personal mobility and freight transport, energy use and CO_2 emissions from road transport are projected to double by 2050, unless robust interventions are put in place.[4] This trajectory threatens to undermine national climate goals and worsen air quality, especially in urban centers already disproportionately impacted by pollution.[5] To address this challenge, India has implemented a comprehensive, multi-tiered policy framework aimed at accelerating zero emission vehicle (ZEV) adoption. The term ZEVs in this report refers to battery electric vehicles, fuel-cell electric vehicles and any other alternative technology that results in zero-tailpipe emissions. However, in India, the majority of the clean technology vehicles registered are under the category of battery electric vehicles. This includes a strategic blend of fiscal and non-fiscal incentives introduced by both national and sub-national governments, support for indigenization through phased manufacturing programs, and targeted production-linked incentive (PLI) schemes designed to bolster the domestic ZEV manufacturing ecosystem and strengthen supply chain resilience.

As a result of these initiatives, India has made notable progress, with ZEV sales exceeding 1.96 million units in the fiscal year 2024-25.[6] However, this figure still represents just 7.49% of total vehicle sales, which stood at approximately 26.3 million during the same period.[7] While current policies and incentives are projected to enable 30-35% electrification of new vehicle sales by 2030, the International Energy Agency's 2023 report highlights the need for at least 50% ZEV adoption within the next decade to stay on track for the nation's 2070 net-zero target.[8]

India has made notable progress, with ZEV sales exceeding 1.96 million units in the fiscal year 2024-25.However, this figure still represents just 7.49% of total vehicle sales, which stood at approximately 26.3 million during the same period.

To truly accelerate India's ZEV transition, addressing barriers and employing new incentives will be key to driving adoption. The slow adoption of ZEVs can largely be attributed to higher upfront costs, a limited variety of ZEV models that match the performance of internal combustion engine vehicles, and a lack of widespread public charging infrastructure. While existing policy efforts have established a strong foundation, supply-side regulations, which target or guide the proportion of ZEVs entering the market, are emerging as a powerful, underutilized lever to drive ZEV adoption.

This report explores how supply-side regulations, which are being successfully leveraged in global markets, can be strategically adapted to accelerate India's zero-emission vehicle transition. The report unpacks the mechanics and impact of leading international policies, distills key design principles, and applies them to India's unique mobility and industrial context. By bridging global best practices with domestic realities, the report establishes a compelling case for the adoption of robust supply-side regulations in India to complement existing demand-side measures. Furthermore, it presents a practical approach for designing and operationalizing ZEV supply-side requirements that can work for India, advancing clean mobility while fostering industrial growth and energy security.

Operationalizing Supply-Side Regulations to Drive up ZEV Adoption: Global Experience

Countries around the world are increasingly employing supply-side regulations as a key strategy to accelerate the transition to ZEVs. Effective supply-side frameworks such as ZEV sales requirements, credit-based regulations, and fuel economy standards—not only enforce compliance but also incentivize innovation, enable legacy automakers to adapt, and attract sustained investment in clean mobility infrastructure. These interventions complement demand-side incentives and provide long-term market certainty, helping countries meet their climate and industrial goals without relying heavily on recurring fiscal subsidies.

By 2023, twenty-nine countries had established clear electrification targets or phasing out ICE vehicles, up from twenty-two in 2021.[9] These mechanisms have proven particularly successful in jurisdictions where policies combine regulatory stringency with market-based flexibility, offering a balanced risk-reward environment. Notably, the supply-side regulations are relatively easier to administer and enforce as compared to programs aimed at consumers, as there are fewer number of manufacturers. Some of the effective national and sub-national level supply-side regulations across the world are given below:

- **California** has led global efforts through the introduction of **Advanced Clean Cars I (ACC I)** in 2012, which integrated vehicle greenhouse gas emissions standards, ZEV requirements, and low-emission vehicle standards into a unified regulatory framework.[10] Building upon this foundation, Advanced Clean Cars II (ACC II) was adopted in 2022, which required that 100% of new passenger cars and light trucks sold in California must be ZEVs by 2035.[11]

  California's long-standing leadership in clean transportation through ambitious supply-side regulations has not only set a powerful precedent but also delivered tangible economic and environmental benefits. In a recent setback, the U.S. federal government moved to overturn California's landmark regulation to phase out gasoline-fuelled cars and trucks by 2035.[12] While this may make enforcement more challenging for the California administration, the experience continues to serve as a valuable blueprint for other markets looking to pursue a more pragmatic and phased strategy. California's story highlights that supply-side regulations are not just about environmental ambition—they are critical to market transformation, offering the predictability needed to align fiscal policy with long-term economic and climate goals.[13]

- **China's Dual Credit Policy**, introduced in 2017, requires automakers to produce and sell New-Energy Vehicles (NEVs) to meet annual credit targets. Through this policy, China aimed to reach 20% NEV sales by 2025 (already achieved) and 40% NEV sales by 2030.[14] The production and sales of NEVs have notably increased by 34.4% and 35.5% year-on-year, and the NEV sales accounted for over 40% of new car sales in China in the year 2024.[15]

- **The United Kingdom (UK)** continues to follow Euro emission standards but has also introduced its own regulations, including the **ZEV sales requirement,** which requires 80% of new cars and 70% of new vans sold to be ZEVs by 2030, with full adoption by 2035.[16]

- To further boost ZEV model availability, the **European Union** has introduced an additional credit system for zero- and low-emission vehicles (ZLEV), incentivizing manufacturers to exceed specific sales targets for electric and hydrogen-powered vehicles.[17] The EU committed to ensuring that all new cars and vans registered in Europe will be ZEVs by 2035 under the 'Fit for 55' proposal, which also includes reducing the emissions of new cars by 55% and new vans by 50% by 2030, as compared to 1990 levels.[18]

Clear national momentum is building, with 27 states and Union Territories announcing ZEV policies—many including penetration goals. Seven of these states have gone a step further by prioritizing the electrification of commercial fleets, a critical segment for emission reduction.

These policies across regions have yielded tangible results, including increased ZEV model availability, reduced prices, growth in ZEV sales, accelerated investment in charging infrastructure, and expanded employment opportunities in the green mobility sector. Crucially, these frameworks have provided policy predictability while reducing the burden on public finances.

India's Opportunity: Transitioning to Supply-Side Regulations for a Sustainable ZEV Future

India stands at a pivotal moment in its clean mobility journey. Clear national momentum is building, with 27 states and Union Territories announcing ZEV policies—many including penetration goals. Seven of these states have gone a step further by prioritizing the electrification of commercial fleets, a critical segment for emission reduction.[19] However, despite these efforts, progress has been uneven, with most goals remaining non-binding and implementation fragmented across states.

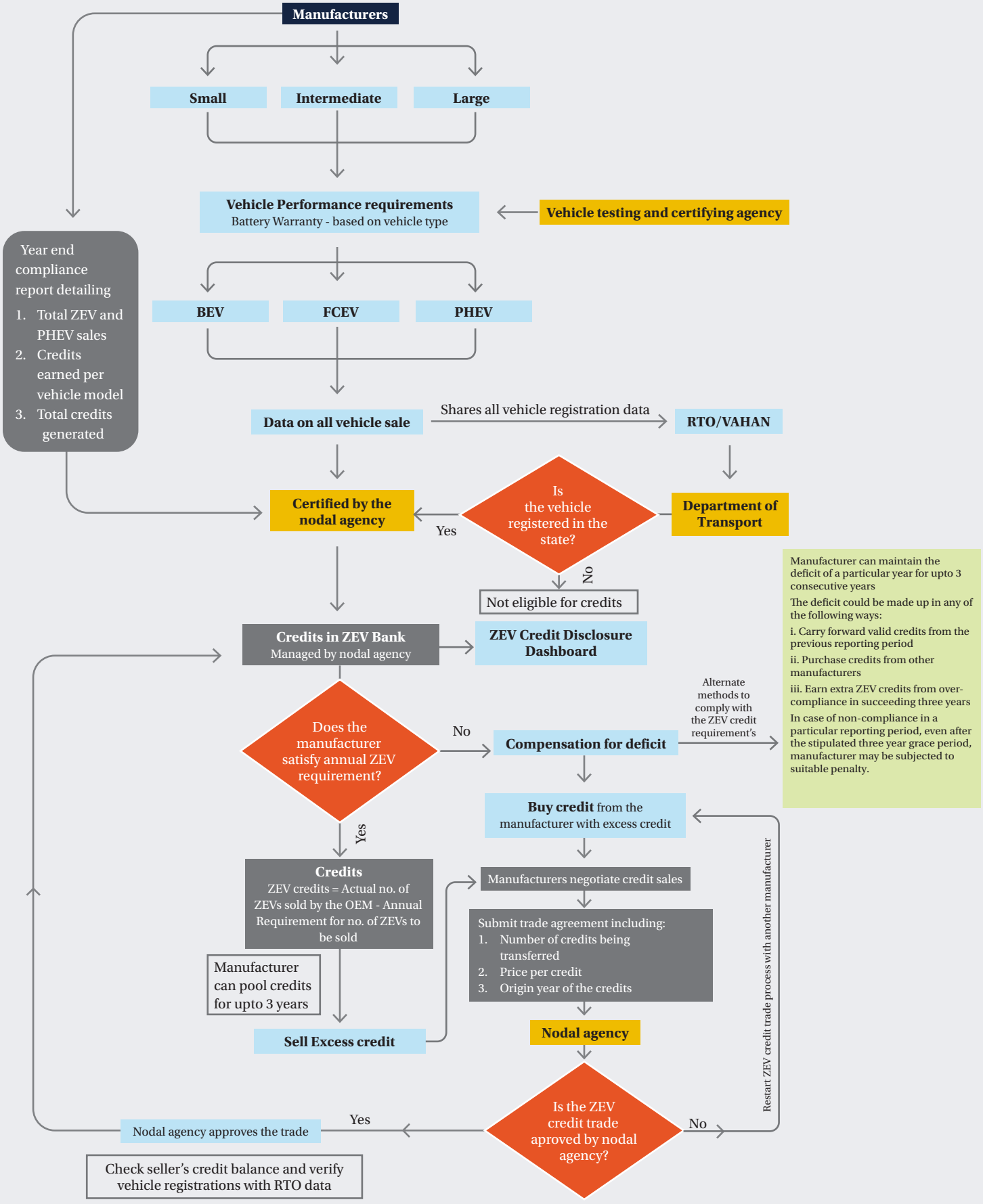
Key Takeaways from the Report:

- Drawing from global experiences, this report identifies **supply-side regulations** as an essential lever with the potential to significantly increase **ZEV model availability, affordability, and overall market readiness.** readiness. Along with complementing demand incentives, supply-side regulations supply-side regulations provide long-term market signals and encourage sustained investment by both manufacturers and infrastructure providers.
- This report proposes a strategy to operationalize supply-side regulation through a ZEV sales-based credit mechanism. This ZEV regulation could be designed at the state level based on the vehicle ownership pattern and automobile manufacturing capability.
- Understanding which vehicle classes are market-ready is essential. To aid policymakers in design, tailored ZEV sales requirements that are both ambitious and achievable, this report provides a comprehensive analysis of ZEV sales data by OEMs across different vehicle form factors such as two-wheelers, three-wheelers (passenger and goods), passenger cars, and light commercial vehicles, which reveals critical insights into market readiness for ZEV sales requirements. The two- and three-wheeler segments show high levels of ZEV penetration, with several OEMs already demonstrating substantial electric sales shares, making them ripe for near-term ZEV sales requirements. In contrast, segments like light goods vehicles and passenger cars remain nascent, warranting a phased, technology-neutral approach.
- Building on global best practices, the report recommends a flexible, credit-based tailored approach that allows early movers to bank or trade credits, offering a self-financing and market-driven mechanism to support the ZEV transition, reducing dependency on direct government subsidies and ensuring fiscal sustainability.

This tailored approach proposes a risk-reward mechanism which is contextualized for India, making it more streamlined and simplified to enable ease of implementation. The proposed approach for the implementation of ZEV regulation in India is captured in the flowchart on following page.

Source: Freepik.com

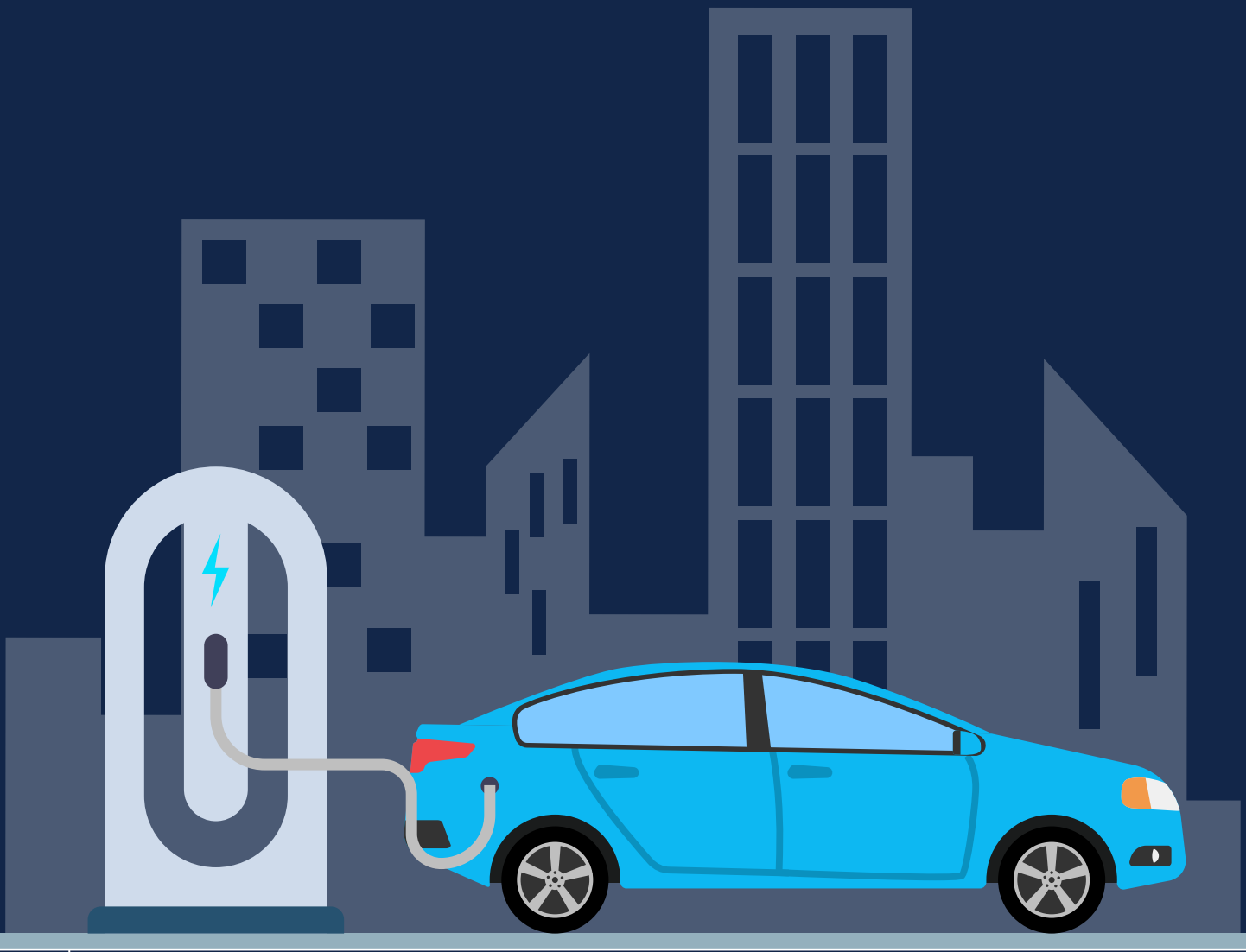
Figure 1. Flow Chart for Implementation of ZEV Regulation in India



Source: NRDC Analysis

The benefits of transitioning to ZEVs in India are profound. If India achieves 100% electrification of road transport by 2043, India is projected to cut crude oil imports by nearly 91%, resulting in cumulative savings of USD 1.92 billion. Additionally, this shift is estimated to reduce carbon emissions by 14 gigatons, an 87% decrease compared to the business-as-usual scenario, between 2024 and 2047.[20] The air pollution reduction resulting from the electrification of road transport is estimated to help prevent 13,300 premature deaths by 2030 and 16,700 by 2040.[21] In parallel, the ZEV transition holds enormous promise for employment generation across manufacturing, R&D, infrastructure, and battery production, positioning India to lead in the global ZEV supply chain. The government's target of achieving a 30% ZEV share of total vehicle sales by 2030 is expected to create 1,20,000 new job opportunities, making ZEVs a key driver for employment.[22]

By adopting tailored supply-side regulations, India can accelerate ZEV adoption while reinforcing its climate ambitions, industrial competitiveness, and energy security. These regulations can provide much-needed **market certainty**, expand the availability of ZEV models across segments, and make clean vehicles more affordable and accessible. With the right policy mix, India is well-positioned to extend its leadership in the global automobile industry and emerge as a powerhouse for emerging clean technologies in the transport sector.



1. Global Trend in ZEV Policies: Shift from Demand-Side Policies to Supply-Side Regulations

Globally, the discourse around Zero Emission Vehicle (ZEV) policies is evolving from being centered around demand incentives to expanding towards market-driven supply-side mechanisms. For years, countries have primarily relied on demand-side policies, such as offering subsidies and incentives, to stimulate ZEV adoption. While these measures have helped kickstart the transition from ICE to ZEV, they place a significant burden on government finances and fail to provide long-term market certainty for industry players. This underscores a critical reality: demand-side policies alone are insufficient to achieve the transformative inflection point needed for a full-scale transition to electric mobility. One of the proven ways to accelerate the deployment of ZEVs is through effective supply-side regulations.

In this report, we delve deeper into analyzing supply-side regulations across major economies, including how they have been designed, their implementation, and their efficacy. The report looks at the status of the automobile sector and vehicle ownership patterns in India, as well as the utility of supply-side regulations to accelerate ZEV adoption in the country. Finally, the report recommends an evidence-based evidence-based tailored approach for for designing credit-based ZEV sales requirements in India, provides a suggested approach for operationalizing them, and outlines the potential benefits of transitioning to ZEVs.

1.1 Shift in ZEV Policies: From Demand-Side to Supply-Side

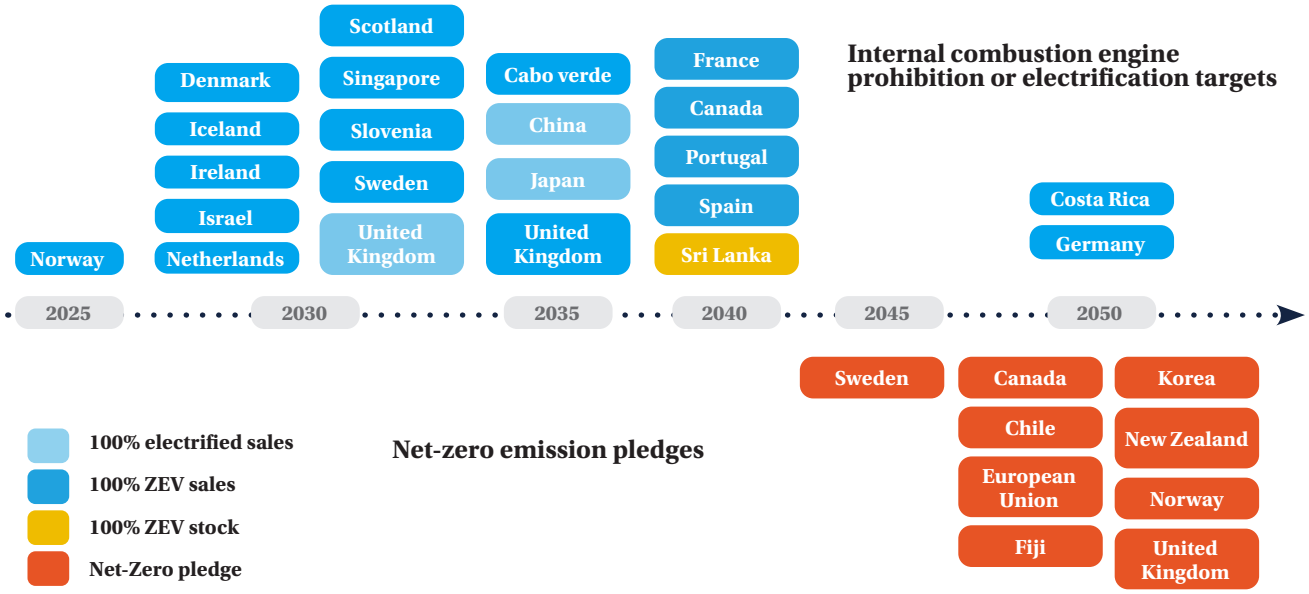
Globally in 2019, the transport sector contributed to nearly 23% of global energy-related CO_2 emissions. Decarbonization of transport thus provides a significant opportunity to reduce CO_2 emissions.[23] Policy measures for supporting clean mobility started gaining momentum and efforts started institutionalizing in 2010, when the Electric Vehicle Initiative (EVI), launched a multi-government policy forum under the Clean Energy Ministerial (CEM), set a target of EV30@30.[24] Given that high upfront cost is a major barrier for ZEV adoption, countries began offering purchase incentives such as rebates at the time of sale, tax exemptions and tax credits along parking fee waivers, toll exemptions, and priority access lanes.[25]

To set a broader target for ZEV adoption, following the EVI, the EV30@30 campaign, with 13 member countries and 23 companies, was launched by CEM in 2017, setting a target of at least 30% new ZEV sales by 2030.

To set a broader target for ZEV adoption, following the EVI, the EV30@30 campaign, with 13 member countries and 23 companies, was launched by CEM in 2017, setting a target of at least 30% new ZEV sales by 2030.[26] Demand-side incentives helped increase the number of ZEVs sold across the world from 320,000 in 2014 to over 17 million in 2024.[27]

The inflection point marks the stage at which sales growth becomes widespread across all market players and is sustained without reliance on subsidies or other forms of policy support. To reach this inflection point for ZEV sales, governments complemented demand-side incentives with effective supply-side regulations, which helped overcome the barriers of price differential, limited availability of affordable ZEV models, and limited charging infrastructure. From the early 1990s, countries began expanding supply-side regulations, such as tightening of fuel and emission standards and introduction of targets for sales of ZEVs. Supply-side regulations became a growing part of the strategy to strengthen the production and sales of ZEVs, as shown in the figure below. By 2021, there were 22 countries that either had electrification targets for either new vehicle sales or vehicle stock and/or had prohibitions on ICE vehicles. Eight countries along with the European Union (EU) had net-zero pledges where the governments committed to reach net-zero emissions by certain target years.[28]

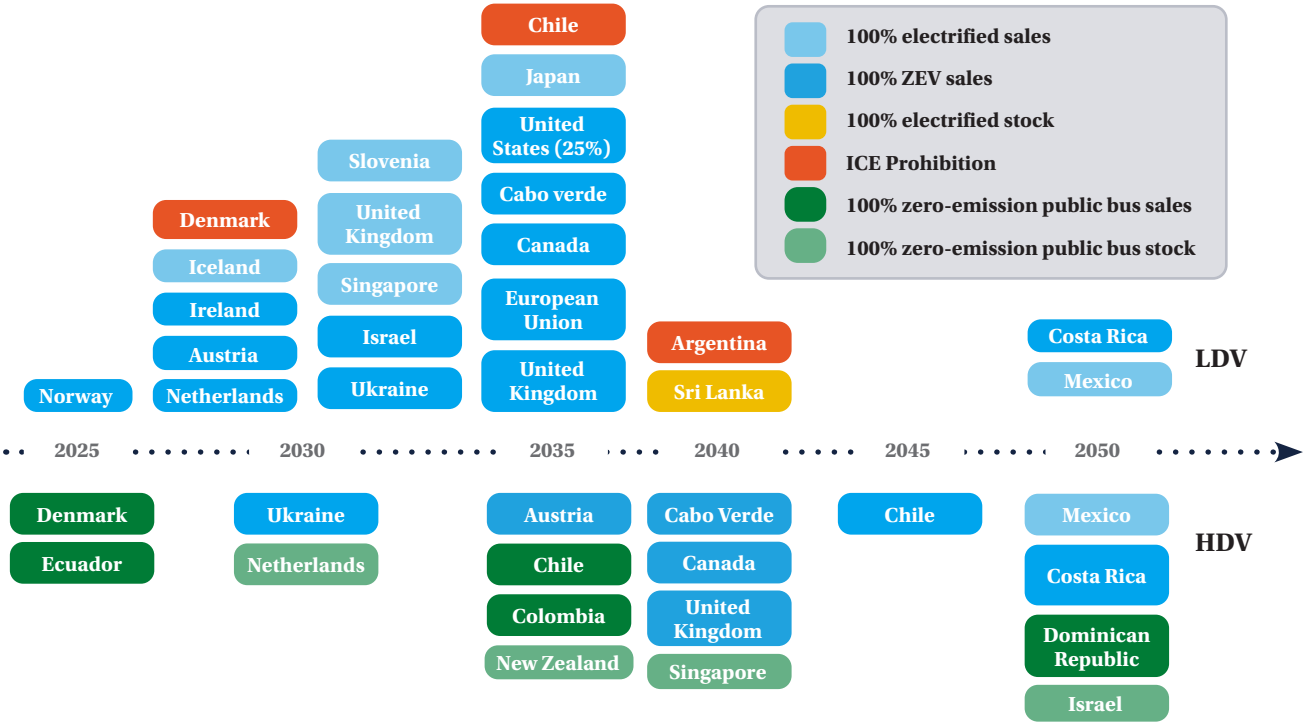
Figure 2. Global Electrification Targets & prohibitions on ICE Vehicles - 2021



Source: International Energy Agency (IEA), Global EV Outlook 2021

Over time, policymakers have also tightened fuel economy standards and emission standards, thereby amplifying the role of ZEVs to meet these standards. By 2021, nearly 85% of car sales across the globe were subject to these standards.[26] In 2023, there were 29 countries with clear electrification targets for either new vehicle sales or vehicle stock and/or a prohibition on ICE vehicles.[9] However, it is important to note that in many of these countries, the targets and prohibitions were non-binding. In Figure 3, we can see that 11 countries and the EU have specifically committed to 100% ZEV sales in different vehicle categories by 2035. While demand incentives were still offered for purchase of ZEVs, the emphasis had shifted to development of supporting charging infrastructure and setting ZEV targets.

Figure 3. Global ZEV Mandates and Prohibitions on ICE Vehicles - 2023



Source: International Energy Agency (IEA), Global EV Outlook 2023

Demand incentives for ZEVs are crucial in early adoption stages; however, once the adoption rates increase and ZEV markets begin to mature, demand incentives may not significantly stimulate ZEV sales as much as supply-side regulations

ZEV adoption rates started increasing in major economies such as China, Europe, and the United States, owing to significant developments such as the implementation of the Inflation Reduction Act (IRA) in the US, the Advanced Clean Cars program by the California Air Resource Board (CARB), and new CO_2 standards in Europe. Over the past decade, more countries began to reduce or phase out demand-side incentives in favor of supply-side regulations.

Demand incentives for ZEVs are crucial in early adoption stages; however, once the adoption rates increase and ZEV markets begin to mature, demand incentives may not significantly stimulate ZEV sales as much as supply-side regulations.[29] Over the years, these supply-side regulations particularly fuel efficiency and emission standards have become substantial, leading to an increase in the cost of manufacturing ICE vehicles as manufacturers are required to improve the existing ICE vehicles with expensive advanced technologies to comply. This shift in cost dynamics has thereby incentivized manufacturers to transition toward the production and sales of more ZEVs.

1.2 Types of Supply-Side Regulations

There are two main types of supply-side regulations (SSRs): performance-based standards and ZEV requirements or sales targets.

- **Performance-based standards:** Performance-based standards can include both emission standards and fuel consumption standards. Emission standards set a limit (per kilometer driven) on pollutants (such as carbon monoxide, nitrogen oxides, particulate matter) that can be released into the atmosphere by the vehicle. Fuel consumption standards set a limit on fuel consumed per kilometer driven. For example, they determine how far the vehicle can travel

on a unit of fuel. These requirements are determined based on either manufacturers' average level or as per-vehicle maximum limit. They are then adjusted based on parameters such as vehicle size, weight, engine power and others. The compliance with these standards is assessed and supported through credit-based mechanisms. Manufacturers earn credits through the sale of low- and zero-emission vehicles. However, super credits or multipliers may be applied, allowing manufacturers to earn additional credits for vehicles with higher environmental performance or when aligned with supported policy programs.

- **ZEV sales-linked targets:** These targets require manufacturers to ensure a certain share of their new vehicles sold are ZEVs. This policy instrument is more direct than the performance-based standards in terms of its mechanisms for incentivizing Original Equipment Manufacturers (OEMs) to manufacture and sell more affordable ZEV models. They provide OEMs with greater policy and market certainty to make investment decisions and support the development of ZEV charging infrastructure.

While demand incentives can support ZEV sales growth for a limited period of time, the supply-side regulations (SSR) can be powerful complementary policy instruments for the longer term. The SSRs include phased targets to phase out ICE vehicles, quotas for ZEV production and sales, emission regulations, and fuel economy standards like CO_2 limits. During the initial phase of ZEV adoption, in the short to medium term, both demand incentives and supply-side regulations must coexist and complement each other.

For a better understanding of the different types of low- and zero-emission vehicles, their definitions are provided below.

Table 1: Definition of types of Electric Vehicles (HEV,PHEV,BEV and FCEV).

Type of Electric Vehicle	Definition
Hybrid Electric Vehicles (HEV)	HEVs are also known as series hybrid or parallel hybrid. HEVs have both engine and electric motor. The engine gets energy from fuel, and the motor gets electricity from batteries.
Plug-in Hybrid Electric Vehicle (PHEV)	The PHEVs are also known as series hybrids. They have both engine and a motor. You can choose among the fuels, conventional fuel (such as petrol) or alternative fuel (such as bio-diesel). It can also be powered by a rechargeable battery pack which is charged externally.
Battery Electric Vehicle (BEV)	Electric Vehicles using BEV technology run entirely on a battery-powered electric drivetrain. The electricity used to drive the vehicle is stored in a large battery pack which can be charged by plugging into the electricity grid. The charged battery pack then provides power to one or more electric motors to run the electric car.
Fuel Cell Electric Vehicle (FCEV)	FCEVs employ fuel cell technology to generate the electricity required to run the vehicle. The chemical energy of the fuel is converted directly into electric energy.

Source: e-AMRIT, NITI Aayog

Supply-side regulations can be highly effective in advancing the adoption of ZEVs by encouraging greater model availability, reducing vehicle prices, and boosting ZEV sales. These policies stimulate investments in charging infrastructure, create employment opportunities, and provide significant health benefits by reducing pollution. While supply-side regulations have been in existence in different forms across countries, it is important to understand their evolution in tandem with the demand incentives that were provided for ZEV adoption.

The next section delves deeper into the evolution of global supply-side regulations in geographies with significant ZEV penetration rates, highlighting the various approaches used to accelerate the global transition to ZEVs.

1.3 Global Case Studies on Designing Successful Supply-Side Regulations

Supply-side regulations in the transport sector have been in place for over five decades. Their origin story began with emission standards, which were introduced in the 1970s to regulate vehicular pollution.[30] The oil price shocks in the early 1970s moved the United States to pass the Corporate Average Fuel Economy (CAFE) standards in 1975.[31] These fuel economy standards provide regulatory certainty for the vehicle manufacturers as they face long investment cycles, therefore enabling them to bring new technologies to the market in a timely manner. These CAFE standards continue to play a key role in decreasing the GHG emissions on average by 2-3% every year.[32]

In developing economies such as India and China, emission standards were introduced in the early 2000s, and they began by adopting the European emission standards. By way of fuel economy standards, countries began to introduce credit mechanisms designed to incentivize the production of vehicles with lower fuel consumption or alternate fuel technologies thereby resulting in lower or no tailpipe emissions. These credit mechanisms in fuel economy standards functioned as self-financing mechanisms that incentivized the achievers and penalized non-compliant OEMs.

Many countries initially introduced supply-side regulations as voluntary measures, and over time, the compliance was made mandatory. This section examines the evolution, design, and implementation of supply-side regulations across different countries and their impact on ZEV sales.

1.3.1 United States

In 2023, the transport sector in the United States accounted for 39% of total energy-related CO_2 emissions, with motor gasoline and diesel consumption accounting for 80% of sector's CO_2 emissions.

In 2023, the transport sector in the United States accounted for 39% of total energy-related CO_2 emissions, with motor gasoline and diesel consumption accounting for 80% of sector's CO_2 emissions.[33] This can be attributed to the high vehicle ownership in the U.S. with over 800 vehicles per 1000 population in 2020.[34] Emission standards for ICE vehicles have been in place for decades in the US and the efforts in this direction began with the establishment of emission standards and the 1975 Energy Policy and Conservation Act. The Act established the corporate average fuel economy (CAFE) standards for passenger cars and light-duty trucks in the USA. This regulation resulted in doubling the fuel economy of cars from 13.6 miles per gallon (mpg) in 1974 to 27.5 mpg by 1985.[35]

In 1991, the US Environmental Protection Agency (EPA) introduced stricter standards that were implemented as successive tiers of regulations phased in over a period of years.[36] Between 1983 and 2004, manufacturers failing to meet the CAFE standards paid more than USD 618 million in penalties.[33] It is estimated that civil penalties ranging from less than USD 1 million to over USD 27 million are paid annually by European manufacturers.[37]

The first GHG standard, which functioned to tighten the supply-side regulations, was introduced in 2012, and it was harmonized with the CAFE standards. Under the GHG program, multipliers were introduced in 2017 for Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), fuel cell electric vehicles (FCEVs), and compressed natural gas (CNG) vehicles. Since then, the multiplier for ZEVs and FCEVs has reduced, while the multiplier for CNG vehicles has increased, which suggests a greater number of BEVs and FCEVs must be produced.[38] The EPA updated these standards for MY 2023–2026, which states that after the manufacturer reaches the requirement between MY 2023 and MY 2024, the multiplier becomes 1 and has no further effect on credit calculations.[39] Under the latest Tier 4 standards, to be phased in from 2027-2033, BEVs and other ZEVs are included in the fleet average calculations for NMOG+NOx, non-methane organic gases (NMOG), and nitrogen oxides (NOx) emissions.[40]

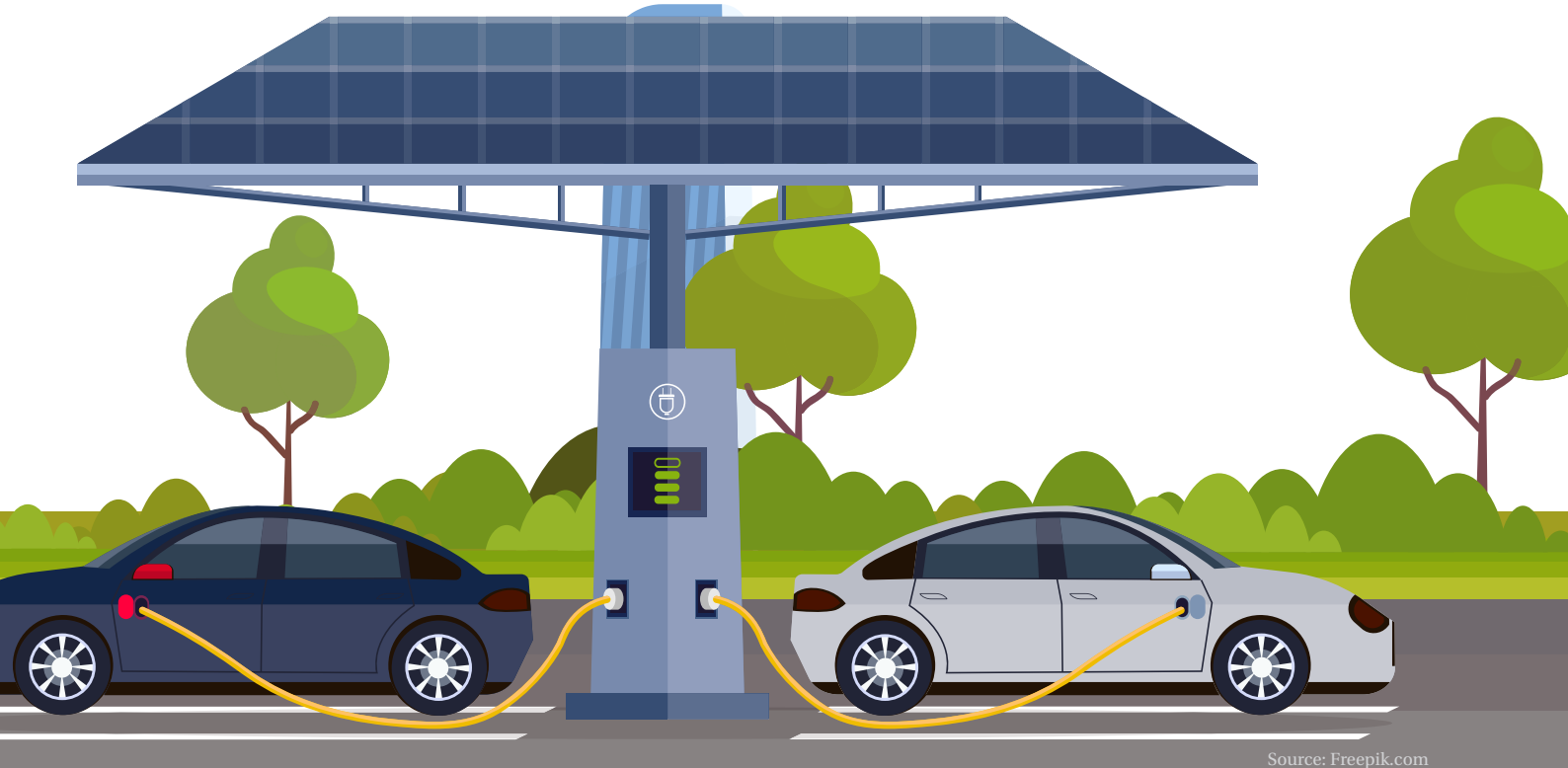
As a result of the risk-reward mechanism of these performance-based standards, the average model year new vehicle CO_2 emissions have been decreasing, and the fuel economy has been on an upward trend.[41]

Transition to zero-emission vehicles: State-level ZEV requirements were first introduced by the California Air Resources Board (CARB) in the 1990s, starting with a 2% ZEV sales requirement. This facilitated a unique policy approach to support the transition from more efficient ICE vehicles to ZEVs, including hybrid models. The 2012 revision of the additional ZEV requirements policy, along with the US EPA's efforts to set national GHG standards, served as a foundation for long-term transition pathways.[42] The federal government, in 2021, set a legally non-binding goal of 50% LDV sales to be electric by 2030.[43] Later, the Federal Sustainability Plan stated that acquisition of LDVs for federal fleets must be ZEVs by the end of fiscal year 2027, and all vehicle acquisitions to be ZEVs by 2035. Presently, after the change in administration in January 2025, the plan to electrify federal fleets has been discontinued.[44]

While at the federal level, there are stringent emission and fuel economy standards as the driving force behind the increase in low-emission vehicles, individual states in the USA have been more proactive and successful in terms of implementing ZEV requirements. In 2013, a memorandum of understanding (MoU) was signed between the states – California, Connecticut, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont, forming the Multi-State Task Force to coordinate and implement policies and programs aimed at transport electrification. In 2020, additional states such as Colorado, the District of Columbia, Hawaii, Maine, North Carolina, Pennsylvania, and Washington joined the ZEV task force and committed to achieve 100% of new sales ZEV in the medium- and heavy-duty categories by 2050 as part of the Multi-State Medium- and Heavy Duty Zero-Emission Vehicle Action Plan.[45] Under the Multi-State Task Force, these states aimed to deploy 3.3 million ZEVs by 2025, and they have collectively achieved this target. To support this goal, states implemented a range of initiatives, including ZEV purchase incentives, dealership engagement, consumer awareness campaigns, development of best practices for charging infrastructure, collaboration with utilities and regulators, electrification of public sector fleets, and support for workplace charging. As a result of collective measures from the member states of the ZEV task force, the ZEV market share of new passenger cars and trucks in 2024 reached 16.7% in the ZEV states as compared to only 6.4% in non-ZEV states.[46]

The following section delves deeper into the California case study, highlighting the state's pioneering role in implementing environmental regulations to decarbonize transport. The key learnings are captured in the section given below.

Under the Multi-State Task Force, states aimed to deploy 3.3 million ZEVs by 2025, and they have collectively achieved this target. As a result of collective measures from the member states of the ZEV task force, the ZEV market share of new passenger cars and trucks in 2024 reached 16.7% in the ZEV states as compared to only 6.4% in non-ZEV states.



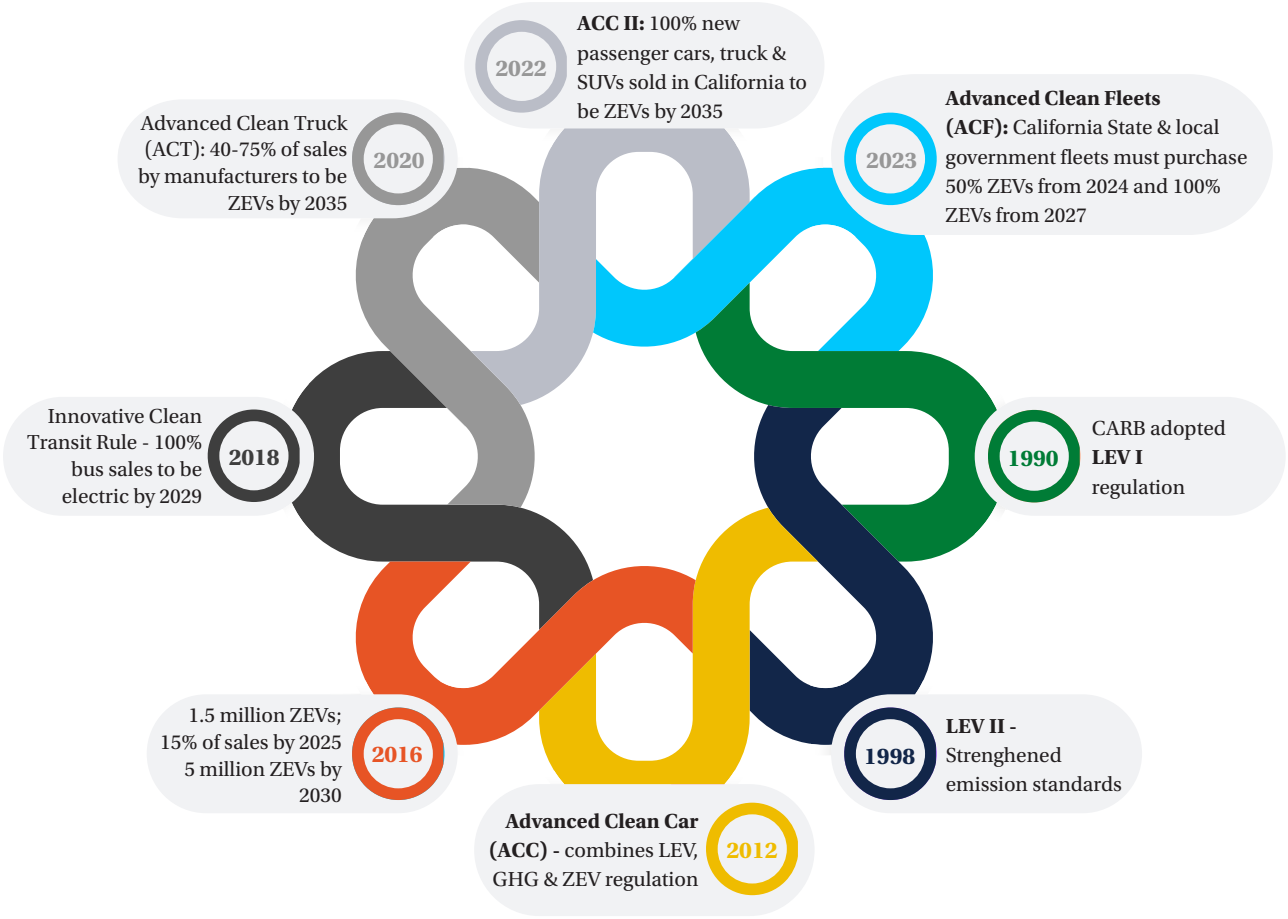
Source: Freepik.com

1.3.1.1 California: Leading the ZEV Transition at Sub-National Level

In California, the transport sector contributed to nearly 39% of the GHG emissions in 2022.[47] Decarbonizing has emerged as an essential focus and the state adopted ZEV regulations to decarbonize road transport. Over the years, California has emerged as a leader in decarbonization efforts, championing the goal of carbon neutrality by 2045.[48]

The California Air Resources Board (CARB) has been proactive for over three decades in championing clean transportation. It first adopted the low-emission vehicle (LEV) regulations in 1990, and these regulations created a mechanism to phase in vehicles of cleaner technologies with an option for credit banking and trading among manufacturers.[49] The journey of LEV regulations in California is depicted in the figure given below.

Figure 4. Evolution of Supply-Side Regulations in California (1990-2022)



Source: NRDC Analysis

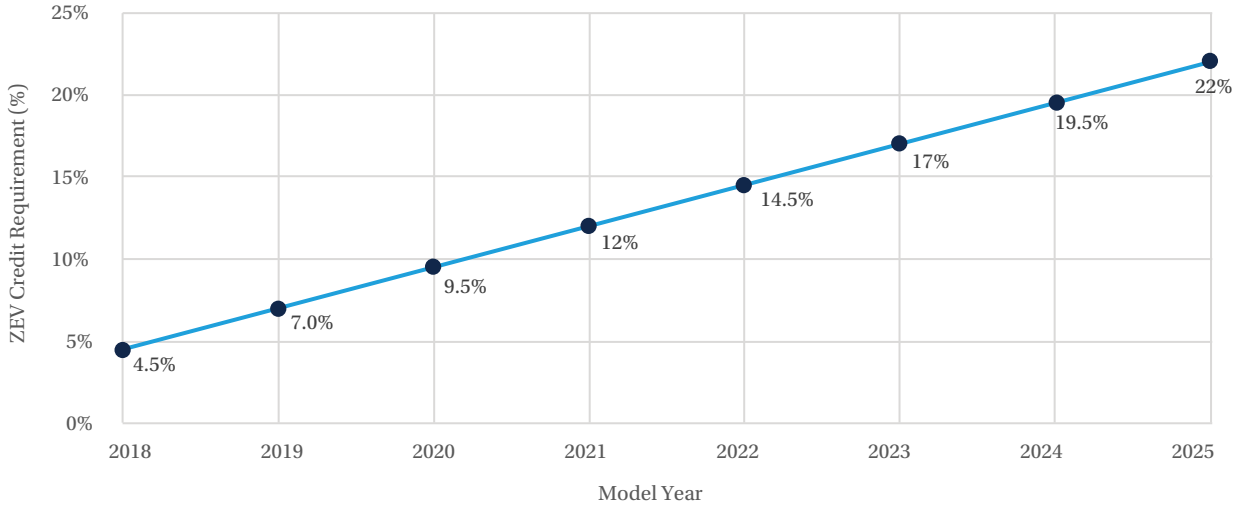
The U.S. Environmental Protection Agency (EPA) granted California, first in 2009, waivers for its clean air and climate program, given its compelling and extraordinary air pollution issues and requirement for more stringent standards. After California obtained a waiver for specified emission standards, the Clean Air Act Section 177 allows other states that were non-compliant with federal ambient air quality standards to adopt California's as their own. These are typically the nonattainment states that have a compelling need to go beyond EPA's standards to reduce certain air pollutants.[50] These waivers provide California the authority to establish and enforce its own, more stringent vehicle emissions standards compared to federal requirements.

California's ZEV Credit System under ACC I program (Model year 2018-25): In 2012, the Advanced Clean Cars (ACC) program was adopted which bundled the LEV regulations, GHG regulations and ZEV regulations into one package. This was to ensure a coordinated package of regulations and incentives built upon previous efforts towards the reduction of pollutants to meet air quality and GHG emission goals.[51]

The ACC I program set increasingly stringent criteria for pollutant and GHG emission limits for new passenger vehicles from 2018 through the 2025 model year. The Zero-Emission Vehicle (ZEV) regulation, a key component of ACC I, required a rising percentage of ZEV and plug-in hybrid electric vehicle (PHEV) sales for manufacturers to achieve compliance with the regulation. In 2019, amid federal rollbacks on emissions policies, CARB reached an agreement with major automakers to voluntarily adhere to stricter GHG standards. From model year (MY) 2018 through MY 2025, the program required manufacturers to meet the ZEV

credit percentage requirement, increasing from 4.5% to 22%, as shown in the figure below. While there were a few exceptions, automakers exceeded expectations and have already surpassed the MY 2025 ZEV sales requirement—MY 2024 ZEV sales in California were about 25%, well above the MY 2025 effective requirement of about 7% ZEV sales (the sales equivalent of a 22% ZEV credit requirement).

Figure 5. ZEV Credit Requirement under ACC I (2018-2025)



Source: NRDC Analysis

The ZEV credit is calculated based on the range per charge of the vehicle. The ZEV credit requirement is the minimum percentage of ZEV credits earned by passenger cars and light-duty trucks manufactured and sold in California. These requirements are assigned to manufacturers based on the annual sales of vehicles by the respective manufacturer in California. The manufacturers were bucketed into three different categories based on the three-year average of the number of vehicles sold in California.[52] Manufacturers with less than 4,500 units of sales were not required to meet the ZEV requirements. Manufacturers who sold more than 4,500 units but less than 20,000 units were given the flexibility to meet all ZEV credit requirements through transitional zero-emission vehicle (TZEV) credits, which were applicable for PHEVs. However, manufacturers selling more than 20,000 units were required to meet a certain amount of ZEV credit requirements through only ZEVs, and the remaining with TZEVs.

The manufacturer must submit a year-end compliance report with details of sales of each type of vehicle and credits earned to credit bank which is managed by CARB. A manufacturer with excess credit can pool or sell to a manufacturer with a deficit. Pooled credits can be used to fulfill a limited percentage of the entire ZEV requirement. Excess credits can be carried forward for 5 years.

Market forces determine the sale or purchase of ZEV credits and the price per ZEV credit. There is no intervention from the regulator in deciding the price of the credit. CARB approves this trade, and the credit ownership transfer is done in the ZEV bank. In case of deficit, where the manufacturer sells fewer ZEVs or TZEVs than required, the manufacturer is given time (up to the next three consecutive model years) to make up for the deficit, and by the fourth year they are subject to a penalty of USD 5,000 per ZEV credit. As of data made available by CARB till January 2025, no automaker has failed to achieve compliance.

The formula to calculate ZEV credits is given below.

ZEV credit = 0.01 x Range + 0.50

While a ZEV with less than 50 miles range will receive zero credits, the maximum credits earned under ACC I program is capped at 4 credits per ZEV.[53]

Transitional Zero-Emission Vehicle (TZEV): It is a PHEV with emissions less than 30 mg/mile and 10-year or 150,000 miles warranty on its battery.

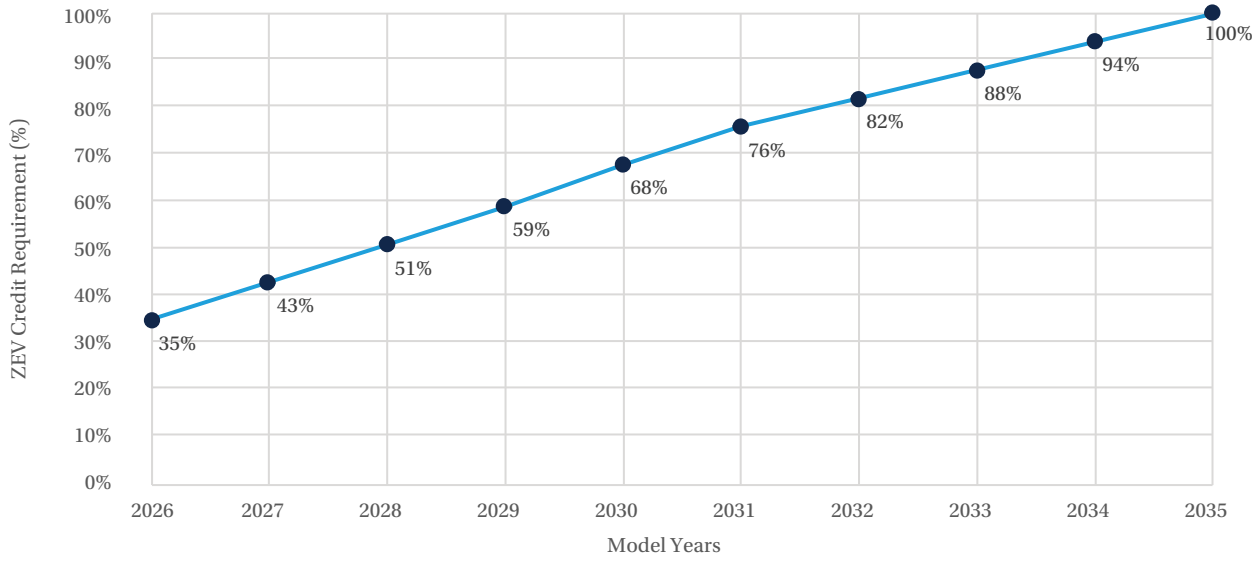
TZEV Credit = 0.01 x EAER + 0.3

Where EAER = Equivalent All Electric Range of a TZEV. While a TZEV with less than 10 miles all electric range receives zero credits, the maximum credits earned under the ACC I program is capped at 1.10 per TZEV.

California's ZEV Credit System under ACC II program (MY 2026-35 and onward): Under the ACC II regulations, California aims to reduce the emissions from new passenger cars, pickup trucks, and SUVs starting from MY 2026 and make them zero-emission vehicles through MY 2035 as shown in the figure given below.[54] The ACC II regulations were released in 2022, giving a lead time of four years for the automobile industry to plan their investments and ramp up their production to meet the yearly ZEV sales targets.

Unlike the ACC I program, both intermediate and large volume manufacturers should comply with the annual ZEV requirement. Small volume manufacturers must also comply with the annual ZEV requirement starting with MY 2035, that is, by 2035, only ZEVs will be produced and sold in the passenger cars and LDT category in California.[55]

Figure 6. ZEV Credit Requirement under ACC II (2026-2035)



Source: NRDC Analysis

The following equation represents the calculation of the annual ZEV requirement for manufacturers.

Annual ZEV requirement (Vehicles) = Annual Percentage Requirement X Production Volume

The manufacturers are provided with flexibility to accrue the vehicle value in four ways:

- ***Sale of ZEVs:*** The ZEVs should have a range of at least 200 miles and also comply with certain requirements such as battery labelling, data standardization, ZEV warranty and charging requirements. The value of one ZEV sale is equal to 1 vehicle value.
- ***Sale of PHEVs:*** The PHEV range should be a minimum of 43 miles through MY 2028 and then it is increased to 70 miles. The sale of PHEV is considered as partial vehicle value and capped at maximum of 0.85.

Partial Vehicle Value = (Certification range value/100) + 0.20

If the PHEV has an all-electric range of at least 10 miles, then an additional credit of 0.15 is provided. However, the maximum partial vehicle value, including the additional credit, may not exceed 1. The OEMs are permitted to count the PHEV sales for up to only 20% of the annual ZEV requirement.

- ***Environmental Justice Vehicle Values:*** There are three ways in which an OEM can earn additional vehicle values.
  - i. If an OEM provides a discount of 25% on the manufacturer's suggested retail price (MSRP) on ZEV or PHEV, provided for use in community-based clean mobility programs, then they earn an additional vehicle value of 0.50 or 0.40, respectively.
  - ii. If an OEM initially leases a new ZEV or PHEV and then sells it at the end of the lease in 2026 through 2031 to a dealership participating in a financial assistance program, an additional vehicle value of up to 0.25 can be earned. However, the MSRP of the ZEV/PHEV should be less than USD 40,000.
  - iii. An additional 0.10 vehicle value can be earned if the ZEV/PHEV is priced below USD 20,275 for passenger cars and below USD 26,670 for LDTs, from MY 2026 through MY 2028.[56]
- ***Early action credits:*** An additional provision is incorporated into ACC II to encourage the sale of ZEVs in the immediate future, prior to the implementation of the regulation in 2026. These early compliance values are derived from the excess ZEV and PHEV sales of the manufacturer in each of the two model years preceding the program's commencement, i.e., MY 2024 and MY 2025 in California.

- At the conclusion of model year 2025, a manufacturer's PHEV and ZEV credit account balances, earned during ACC, will undergo a one-time conversion according to the following equations:

Converted ZEV value = (2025 MY ZEV credit balance)/2.1

Where the converted ZEV values will be rounded to the nearest whole number and in a similar way, the PHEV credits also will be converted.

Other Section 177 states that adopt ACC II at a later date may have a different commencement year. This provision allows manufacturers to carry forward ZEV sales that exceed the 20% threshold in each of the two model years preceding the program's start (e.g., MY 2024 and MY 2025). Similarly, a 7 percent threshold applies to states with comparatively lower baseline ZEV adoption, thereby offering regulatory flexibility in markets that have not yet reached higher levels of penetration. These surplus sales can be used to generate ZEV values during the first three model years after the ACC II program begins. The value is limited to 1 for ZEV and less than or equal to 1 for PHEV, contingent upon the electric range and the ACC II PHEV value calculation. Only 15% of the annual requirement for the model year can be derived from the early action credits.

If there are excess credits, the OEM can trade them with another manufacturer. These credits can also be traded between manufacturers in California and Section 177 states to help achieve compliance. The manufacturers enter into a private trade agreement where they negotiate the credit sales according to market value. A trade agreement is made with information on the number of credits being transferred, the price per credit decided by both parties, and the origin model year of the credits. The trade agreement is approved by CARB, which checks seller's and buyer's credit balance, verifies with the Department of Motor Vehicles (DMV) data and changes the ownership of the credits in the ZEV bank upon approval.

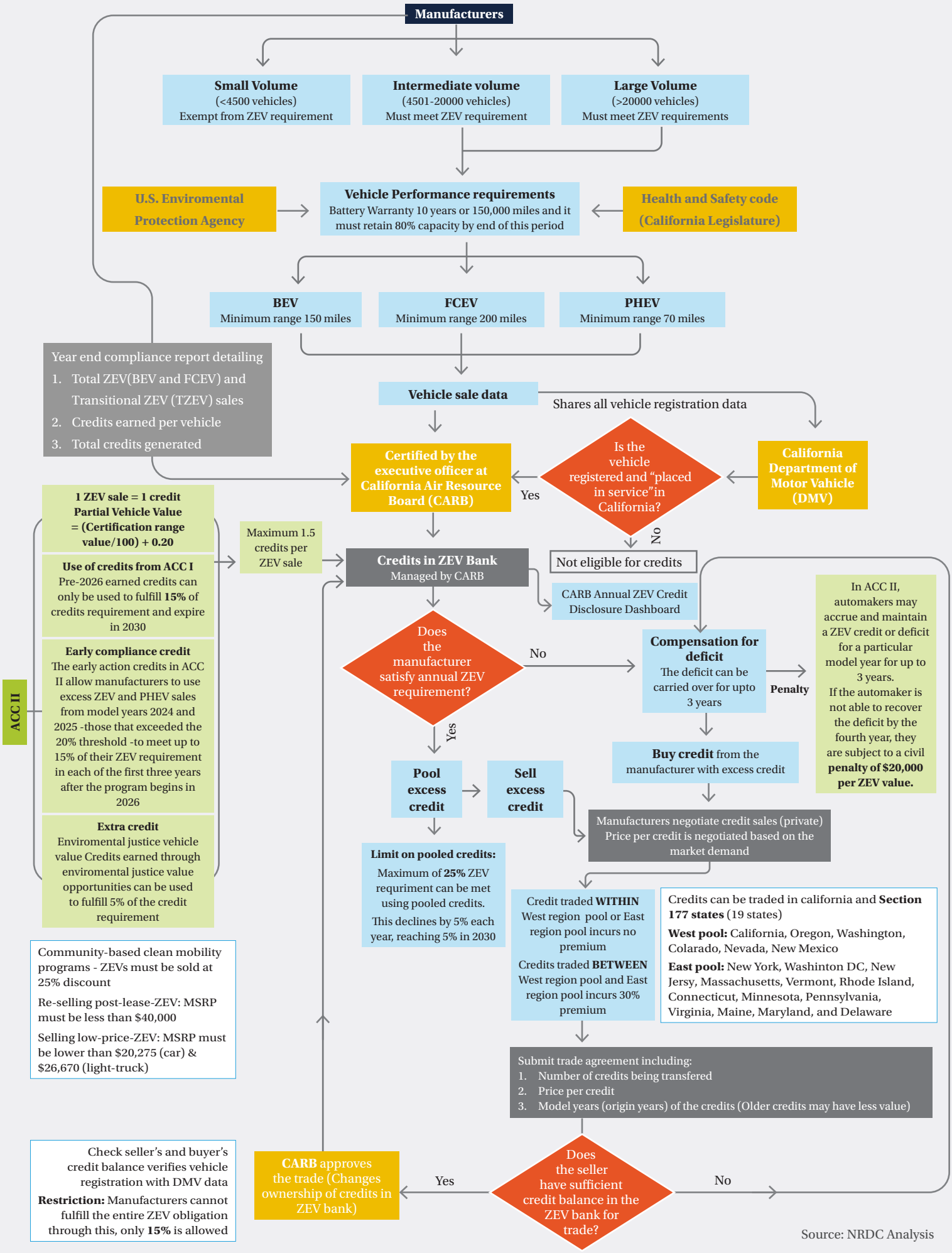
In case of deficit, the OEMs are given a time of three years to equalize their deficits through the accrual of vehicle values, subject to certain conditions. Under the ACC program, if a manufacturer failed to recover the deficit credits even after three years, then a civil penalty must be paid which acts as a deterrent for non-compliance. The amount of the civil penalty is USD 20,000 per ZEV for MY 2026-2035.[57]

Since 2014, under the ZEV regulations, 27 OEMs have generated credits which resulted in a cumulative sale of 1.68 million through MY 2023. It is notable that BEVs accounted for 90% of all ZEV credit-earning sales in MY 2023 and the BEV sales more than doubled from MY 2022.

Source: Freepik.com

The process flow chart for the implementation of the ACC II program in California is given below.

Figure 7. Process flow for Advanced Clean Car Program in California

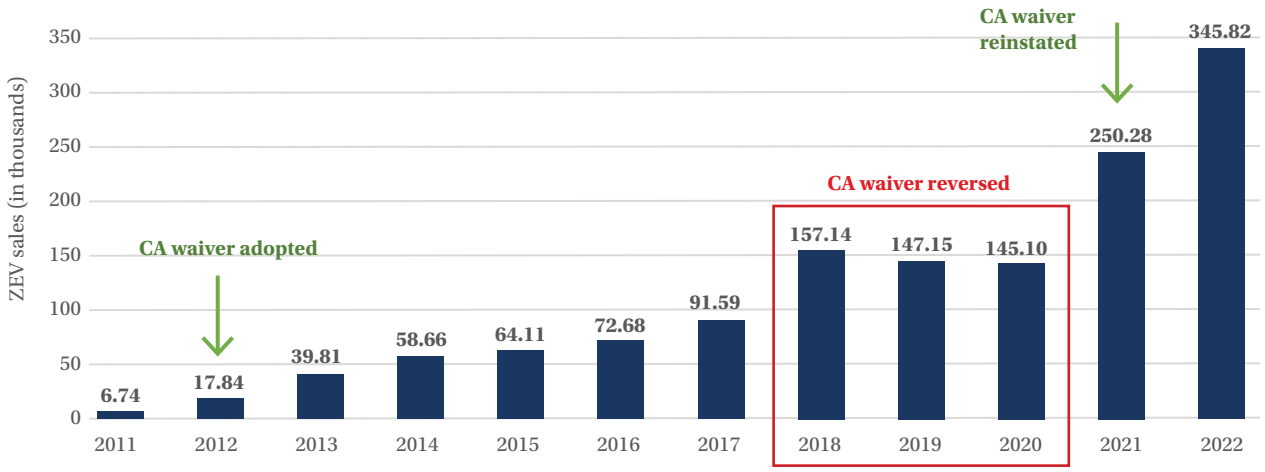


Source: NRDC Analysis

The success of the ACC program is witnessed in California and 17 other states in the USA.[58] The Section 177 of Clean Air Act authorizes other States to choose to adopt California's standards in lieu of federal requirements.[59] Since 2014, under the ZEV regulations, 27 OEMs have generated credits which resulted in a cumulative sale of 1.68 million vehicles under the ZEV regulations through MY 2023. It is notable that BEVs accounted for 90% of all ZEV credit-earning sales in MY 2023 and the BEV sales more than doubled from MY 2022. PHEVs were nearly 60% of the ZEV credit-earning sales in 2014, but this share reduced to 10% by MY 20-23. This indicates that the ACC program increased BEV sales by offering BEVs more credits than for PHEVs.[60]

The effect of ACC program on ZEV sales in California and across US became evident when California ZEV sales began to stall in 2018, when the federal government revoked California's waiver to enforce supply-side regulations and also weakened the national GHG standards.

Figure 8. Increase in ZEV Sales in California due to State and Federal-Level Regulations



Source: California Energy Commission LD ZEV sales data and United States Department of Energy Vehicle Technologies Office

As shown in figure above, in 2021, ZEV sales increased again directly following industry confidence that the California waiver would be reinstated, and national standards would be strengthened by the government.[61]

The ZEV sales in California sharply increased in 2017-2018, when the ACC I program was enforced. In the fourth quarter of 2024, ZEVs represented 25.1% of all new vehicle sales in California, surpassing the target of 22% ZEV credit requirements to be achieved by 2025.[62] However, under ACC I, the requirement was credit-based meaning the actual ZEV sales needed to meet the target were much lower due to how credits were awarded based on vehicle range (0–4 credits per vehicle). As a result, the effective sales requirement was only about 7–9%, rather than the stated 22%. In contrast, the ACC II program has simplified and streamlined the credit system by assigning one credit per ZEV sold, making the percentage requirement directly reflect actual vehicle sales. It is estimated that by setting a target of 100% ZEV sales by 2035, there is a massive opportunity to reduce 1.3 gigatons of carbon emissions and create 300,000 new jobs by 2050 in California created as a result of the expansion of manufacturing facilities and the deployment of charging infrastructure.[63]

California's long-standing leadership in clean transportation through ambitious supply-side regulations has not only set a powerful precedent but also delivered tangible economic and environmental benefits. In a recent setback, the U.S. federal government moved to overturn California's landmark regulation to phase out gasoline-fuelled cars and trucks by 2035.[64] While this may make enforcement more challenging for the California administration, the experience continues to serve as a valuable blueprint for other markets looking to pursue a more pragmatic and phased strategy.[65]

For decades, California had the authority under the Clean Air Act to set stronger emissions standards than the federal baseline—an essential tool in fighting the state's severe air pollution and advancing its broader climate goals. Its bold policies catalyzed a de facto national ZEV mandate, influencing 11 other states and demonstrating how regulatory certainty can unlock industrial growth.[66]

An evidence of how critical these supply-side regulations have been in boosting the industry and creating jobs is reflected in the strong support from the California State Association of Electrical Workers, which has opposed efforts to weaken the state's clean vehicle standards. They highlight that the clean transportation sector has attracted billions in public and private investment and the fact that the regulations fuel job creation, industrial innovation, and grid modernization.[67]

California's story highlights that supply-side regulations are not just about environmental ambition—they are critical to market transformation, offering the predictability needed to align fiscal policy with long-term economic and climate goals.

BEVs, FCEVs and PHEVs with an electric range of at least 50 km were counted as 2.0 in 2021, but it decreased to 1.0 in 2025, thereby enabling the sale of higher number of clean technology vehicles.

Catalyzing Zero-Emission Truck Sales in the US through Advanced Clean Trucks (ACT)

The Advanced Clean Trucks (ACT) regulation, first adopted by CARB in June 2020, requires truck manufacturers to sell an increasing share of zero-emission trucks (ZETs) each year. The rule is structured across three vehicle categories, with targets to be reached by 2035:

- 55% of new Class 2b–3 pickup trucks and vans,
- 75% of new Class 4–8 rigid trucks, and
- 40% of new Class 7–8 tractor trucks must be zero-emission vehicles.[68]

ACT ensures a reliable and growing supply of ZETs, aligning with ongoing technological advancements, cost reductions, and infrastructure development.[69] To further stimulate demand, CARB also adopted the Advanced Clean Fleets (ACF) regulation, which sets complementary fleet transition requirements.[70]

Early outcomes highlight the regulation's effectiveness: as of June 2023, over 17,500 ZETs were deployed across all 50 U.S. states. Notably, the ACT-adopting states represented just 25% of total truck registrations but accounted for 38% of ZET deployments, demonstrating the regulation's catalytic impact on market uptake. As of May 2024, 11 states, including California, adopted the ACT regulation, covering 27% of the U.S. medium- and heavy-duty vehicle (MHDV) market and accounted for 37% of national ZET deployments. By 2030, ACT and ACF compliance is projected to result in the deployment of at least 461,000 ZETs across these states.

1.3.2 China

In 2019, the road transport sector in China accounted for 10% of China's GHG emissions and 43% of its oil consumption.[71] Decarbonization of the transport sector is expected to play a critical role in achieving its net-zero goal by 2060. To tackle the issue of growing vehicle emissions in the country, China has implemented various supply-side regulations to promote low- or zero-emitting vehicles.

China introduced vehicle emission standards in 2000 based on European standards, and since then has steadily tightened its standards and made them even more stringent than European regulations.[72] Complementing the emission standards, China introduced its first fuel economy standard in 2004 and over the years, the fuel economy standards, such as the Corporate Average Fuel Consumption (CAFC) standards, have become more stringent, leading to increased production of alternate fuel vehicles by manufacturers to effectively meet these standards. In the later stages of the fuel economy standards, flexibility was provided to incentivize energy-efficient vehicles such as BEVs, PHEVs, and FCEVs. Greater multipliers are provided for vehicles with lighter fuel consumption with gradually decreasing weights. BEVs, FCEVs and PHEVs with an electric range of at least 50 km were counted as 2.0 in 2021, but it decreased to 1.0 in 2025, thereby enabling the sale of higher number of clean technology vehicles.[73] To further mitigate the air pollution, reduce reliance on fossil fuels and increase the manufacturing and sale of alternate fuel vehicles, the Dual Credit policy was implemented.

Dual Credit Policy: The Ministry of Industry and Information Technology (MIIT) in China enforced the New-Energy Vehicle (NEV) mandate policy in 2018, which applies to PHEVs, BEVs, and FCEVs.[74] Through this policy, China aimed to achieve 20% NEV sales by 2025 (already achieved) and 40% NEV sales by 2030.[75] The MIIT introduced the dual credit policy, where automobile companies with annual production/import of more than 30,000 passenger vehicles have to fulfil both the CAFC and NEV credit requirements.[76] To comply with this policy, the manufacturers must produce and sell enough NEVs to meet or exceed their annual credit targets.

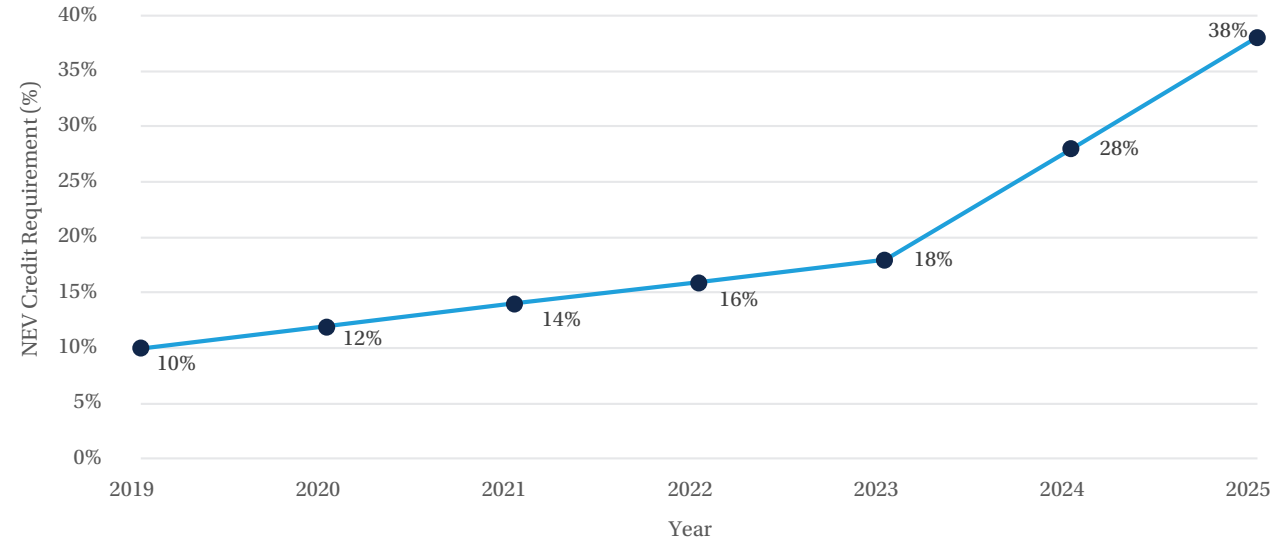
The formulae to calculate these credits are given below:

CAFC Credits = (CAFC Compliance Value – CAFC Actual Value) X Passenger car production volume or import volume

NEV Credits = (NEV credits per vehicle x Production Volume) – NEV Compliance Value

The BEVs would qualify for up to 6 NEV credits if they had a minimum range of 100 km and a maximum speed above 100 km/h. The PHEVs would qualify for up to 2 credits if they had a minimum electric range of 50 km, and FCEVs with a minimum range of 300 km would qualify for up to 5 credits. As shown in the figure below, the annual credit requirement increases from 10% in 2019 to 38% in 2025.[77] Alike the California ZEV regulation, the annual percentage targets are for the NEV credits and not for NEV sales.

Figure 9: NEV Credit Requirements for Light-Duty Passenger vehicles in China (2019-2025)

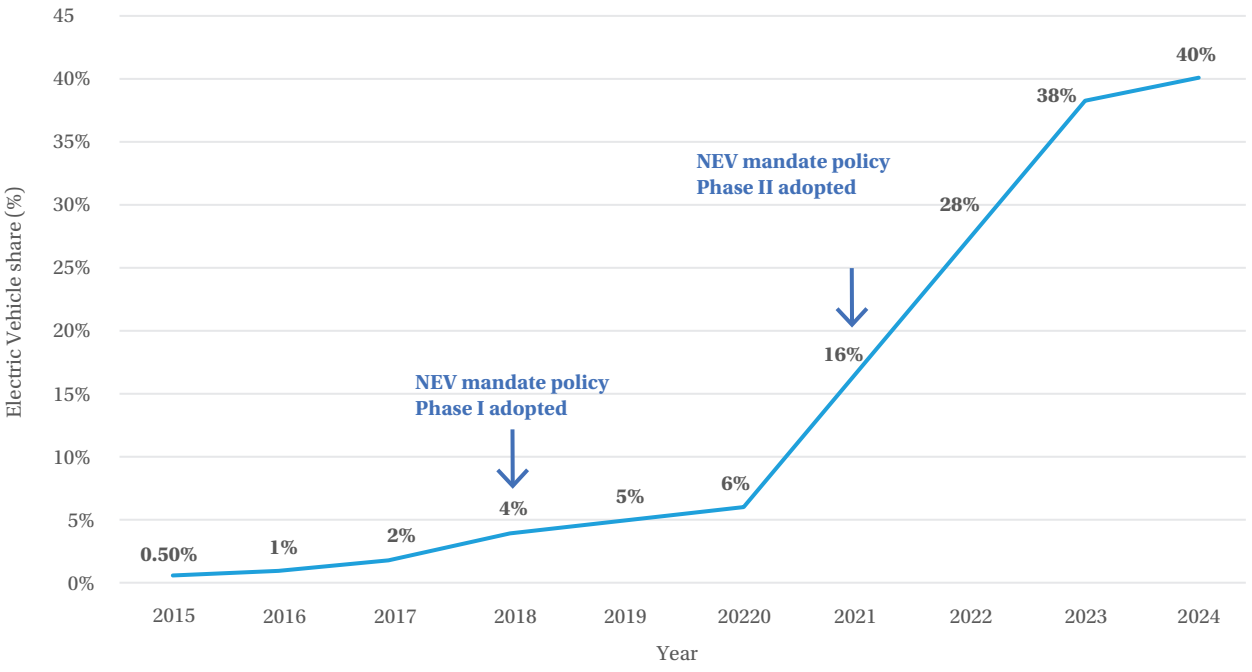


Source: DieselNet

The manufacturer, falling under the ambit of the dual credit policy, must meet both the CAFC and NEV credit requirements. Surplus NEV credits can be sold to other manufacturers or used to offset CAFC credit deficits. However, CAFC credits cannot be used to meet NEV credit requirements. This dual credit policy, therefore, significantly encourages NEV production.[78] While the manufacturer is incentivized for producing NEVs, he is prohibited from selling non-compliant vehicles unless his negative credits are not zeroed out. However, if a manufacturer is unable to equalize his negative credits to zero, he must submit an adjustment plan to MIIT and set a deadline for compliance.[79]

NEV growth and policy impact: By December 2022, the national demand-side subsidy scheme for NEVs ended, and 2023 was the first year when China's NEV industry functioned without subsidies. The purchase subsidies were phased down gradually by the central government, and even the city-level upfront purchase subsidies were scaled down.[80] Contrary to the belief that the ZEV industry growth was dependent on demand incentives, China witnessed increased price competition and consolidation of NEV sales.

Figure 10: Share of Electric Vehicles (BEV+PHEV) in total new car registration from 2015 to 2024 in China



Source: BNEF, ING Research

According to the NEV Industry Development Plan, a 20% NEV sales target was set for 2025.[71]. However, in March 2023, NEV sales surpassed 40% of overall car sales for the first time in China. A target of 45% NEV sales was set for 2027.[81] The production and sales

of NEVs have notably increased by 34.4% and 35.5% year-on-year, and the NEV sales accounted for over 40% of new car sales in China in the year 2024.[82]

1.3.3 European Union

The production and sales of NEVs have notably increased by 34.4% and 35.5% year-on-year, and the NEV sales accounted for over 40% of new car sales in China in the year 2024.

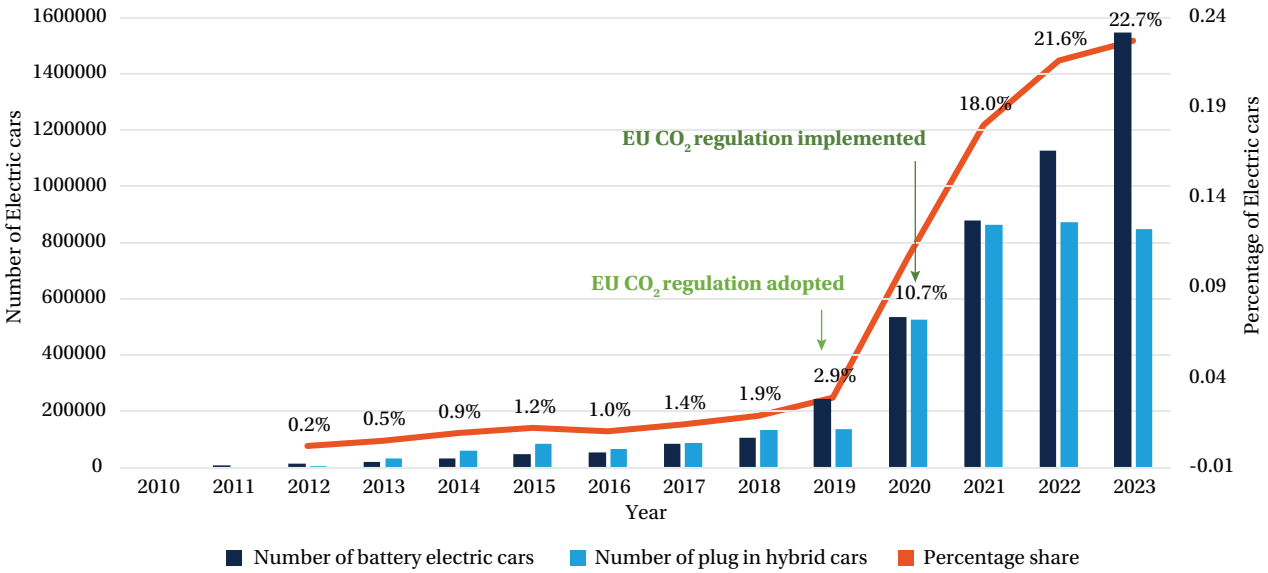
Historically, the European Union (EU) has been progressively implementing regulations to address vehicular emissions through emission standards and updating them from time to time. Since 1992, the European Commission has focused on reducing carbon dioxide emissions and other pollutants through the Euro emission standards.[83] In 2022, road transport contributed to 73.2% of the EU's total GHG emissions (including domestic and international transport), indicating the need for strengthening the Euro standards and fostering the ZEV ecosystem.[84] The Euro 7 standards, to be enforced from 2026, will impose the same emission limits on all motor vehicles, regardless of the fuel used in the vehicle (including alternative fuel technologies like electric, hybrid, and hydrogen fuel vehicles). This will be the first emission standard across the world to set limits on particulate emissions from brakes and tyres, in addition to the limits on tailpipe emissions.[85]

However, to ensure that the cost of compliance was less than that of non-compliance, a penalty in the form of an excess emissions premium was imposed if the manufacturer's fleet average CO_2 emissions exceeded the limit value. The premium, from 2012, was EUR 5 for the first g/km, EUR 15 for the second g/km, EUR 25 for the third g/km, and EUR 95 for each subsequent g/km. However, from 2019 onwards, from the very first g/km of excess, the manufacturer must pay EUR 95.[86]

The second round of CO_2 emission standards for new cars and vans were released in 2019 and these stricter CO_2 targets were implemented from 2020. These emission standards incentivize manufacturers to produce more fuel-efficient ICE vehicles, and to promote manufacturing and sales of zero- and low-emission vehicles (ZLEV). In addition, the EU introduced an added incentive mechanism. From 2025 to 2029, if the manufacturer's new sales for ZLEV cars exceed 25% and new ZEV vans exceed 17%, then the specific emission target for the manufacturer will be reduced (capped at a maximum of 5%).[87] This is not a mandate but a voluntary target and a compliance flexibility mechanism.

Manufacturers who exceed the voluntary targets are eligible for relaxation on their corporate average GHG standards. Vehicles with emissions lower than 50 gCO_2/km are eligible for credits and the ZEV percentage target is 15% share of new vehicles for 2026-2029 and 35% for 2030. Low-emission vehicles give the manufacturer partial credit towards this target, while BEVs and FCEVs give manufacturers full credit towards this goal.[88] Each eligible passenger car was counted as 2 passenger cars in 2020, 1.67 passenger cars in 2021, 1.33 passenger cars in 2022, and 1 passenger car in 2023. As shown in the figure below, the new CO_2 emission standards in 2020 led to increase on ZEV sales from 2.9% in 20219, with nearly 8 times the increase, to 22.7% in 2023.

Figure 11: Electric cars (BEV+PHEV) sales in the EU from 2010 to 2023



Source: European Environment Agency

With a goal to accelerate ZEV adoption and make the EU climate-neutral by 2050, that is to achieve a balance where the net GHG emissions of the EU are zero, the member countries of the EU adopted a new legislation "Fit-for-55".

Fit for 55 Deal (2022): The EU committed to ensuring that all new cars and vans registered in Europe will be ZEVs by 2035. The 'Fit for 55' proposal also includes reducing the emissions of new cars by 55% by and new vans by 50% by 2030, as compared to 1990 levels.[89]

It is notable that the automotive industry in the UK had begun to sell 56% more electric cars in FY 2023-24 as compared to the previous year in order to meet the ZEV target of 80% for cars by 2030.

1.3.4 United Kingdom

The domestic transport sector accounted for 28% of the GHG emissions in the United Kingdom (UK), in 2022, and therefore decarbonization of the transport sector is crucial to achieve the UK's net-zero target for 2050.[90] The UK was a part of the European Union till January 2020 and adopted the same vehicle emission regulations as the rest of Europe, following the Euro 1 through Euro 6 policies. Even after its exit from the EU, it was decided that the UK will continue to adopt the Euro standards.[91]

To improve ZEV availability and to accelerate its adoption, the UK adopted the Zero-Emission Vehicle (ZEV) Mandate law in 2024. As a part of this law, new petrol and diesel cars will not be allowed to be sold starting in 2030; however, hybrid cars can be sold till 2035, and ICE vans can be sold alongside full-hybrid and plug-in hybrid vans till 2035. Small volume manufacturers, with less than 2,500 cars/vans annual sales in the UK, are exempted from this phase-out.[92]

The manufacturers must meet their targets either by increasing their ZEV sales or by trading credits with other manufacturers who have them in excess. In case the manufacturer overshoots the target, they will be allowed to bank or trade them with other manufacturers.[93] Flexibility has been provided for manufacturers to transfer credits from non-ZEV sales to ZEV sales till 2029. For example, 1 car credit can now be exchanged for 0.4 van credit, and 1 van credit can be exchanged for 2 car credits between manufacturers.[94]

The penalty for non-compliance with the emissions target and sale of non-ZEVs is given below:

- If the manufacturers miss their fleetwide average CO_2 emissions target, then a payment of GBP 86/g of exceedance must be paid.
- On average, the sale of a non-ZEV car instead of a ZEV would lead to payment of GBP 12,079 (USD 15,340) and
- GBP 17,262 (USD 21,923) for sale of average non-ZEV van.[95]

The ZEV mandate accelerated sales of ZEVs in the UK in 2024, reaching a total of 19.6%, exceeding the 18% target.[96] It is notable that the automotive industry in the UK had begun to sell 56% more electric cars in FY 2023-24 as compared to the previous year in order to meet the ZEV target of 80% for cars by 2030. According to research, it is estimated that the ZEV market in the UK is projected to grow 8.59% between 2025 and 2029.

The table below summarizes the supply-side regulations that have been used across various countries that are leading ZEV sales globally.

Table 2. Summary of Effective Supply-Side Regulations Across Key Countries

	California and other U.S. States		China	EU	UK
Policy	ACC I	ACC II	NEV mandate policy	Euro standards (1 to 7) and Fit-for-55 deal	ZEV mandate
Year	Model year 2012-2025	Model year 2026-2035 and onwards	2018-2023 2024-2030	2024-2035	2024-2035
Target	22% ZEV credits (7% ZEV sales) by 2025 applicable to light-duty passenger cars, pickup trucks and SUVs	100% ZEV sales by 2035 applicable to light-duty passenger cars, pickup trucks and SUVs	20% NEV sales by 2025 40% NEV sales by 2030	15% ZEV sales by 2029 35% ZEV sales by 2030 100% ZEV sales for new cars and vans by 2035	80% new cars & 70% of new vans sold must be zero emission by 2030 100% by 2035

	California and other U.S. States		China	EU	UK
Vehicle eligibility –	Minimum ZEV range - 50 miles	Minimum ZEV range - 200 miles	Vehicles with new-type power systems, completely or mainly driven by new-energy sources, including PHEVs, BEVs, and FCEVs.	Vehicles with emissions lower than 50 gCO_2/km	Minimum ZEV range - 100 miles
Manufacturer eligibility	Minimum 4,500 units of production annually	Minimum 4,500 units of production annually	Minimum 30,000 units of passenger vehicles produced annually	Manufacturers responsible for minimum 1000 new cars or 1000 new vans registered in EU	Manufacturers responsible for minimum 1000 new cars or 1000 new vans registered in EU
Credit system	The credit is equal to 1% of vehicle range and adding 0.5	All eligible ZEVs earn 1 credit	Total credits are equal to CAFC credit and NEV credit in 1:1 ratio	The system will alleviate a manufacturer's specific emission target if its new sales for ZLEV cars exceed 25% and new ZEV vans exceed 17%	All eligible ZEVs earn 1 credit
Extra credit	None	Sales of used ZEV (0.25) ZEV sold through community-based discount program (0.5) ZEV sold at 25% discount (0.4) Sale of low-cost ZEV (0.1)	None	None	0.5 extra credit for ZEV sold to car clubs and ZEVs with wheelchair accessibility
Max credit possible	4	1.5	6	-	1.5
Penalties	The manufacturer is given time of 3 model years to make up the deficit USD 5000 per ZEV credit deficit	The manufacturer is given time of 3 model years to make up the USD 20,000 per ZEV sale deficit	Credit shortfall must be offset by purchasing credits from other manufacturers or by producing more NEVs	2019 onwards, first g/km of excess, the manufacturer must pay EUR 95.	Payment of GBP 86 per gram of exceedance of CO_2 emission limit must be paid
Impact	In the fourth quarter of 2024, ZEV represent 25.1% of new vehicle sales surpassing the target of 22%		Sales of NEVs increased by 34.4% in 2023 as compared to 2022	The sale of electric vehicles in the EU rose significantly from 3% of new sales in 2019 to 20% in 2021.	ZEV represent 19.6% of new vehicle sale in UK (2024)

Global case studies such as the United States, Europe, China, and the UK illustrate that it is essential to have a well-balanced risk-reward mechanism: it can incentivize early adopters and companies to innovate, while enabling legacy automakers to adapt and compete in the energy transition. The key benefits of supply-side regulations for ZEV adoption are explained in the next section.

1.4 Demonstrated Benefits of Supply-Side Regulations for ZEVs

Initially, countries relied on demand-side incentives to foster ZEV adoption and boost local manufacturing, however, it is increasingly evident that demand-side policies alone are not sufficient to drive ZEV transition. Gradually, supply-side regulations were strengthened to accelerate ZEV adoption. Research shows that supply-side regulations, particularly ZEV sales requirements, have proven to be the most cost-effective way of driving industry and market transition.[97] Some of the key benefits of supply-side regulations are listed below.

in California, at the beginning of ZEV regulation in the 1990s, there were about three models of ZEVs available in the market. As of 2024, California had close to 269 models of light-duty BEVs and PHEVs.

- **Boosting Model Availability:** Supply-side regulations encourage OEMs to expand their offerings. For example, in California, at the beginning of ZEV regulation in the 1990s, there were about three models of ZEVs available in the market.[98] As of June 2024, California has close to 100 models of light-duty BEVs and PHEVs, which further increased to over 140 by the end of 2024.[99,100] States with lower levels of ZEV regulation and sales, such as Wyoming or North Dakota have less than ten models available in comparison.[101]

  Canada's ZEV mandates aim for 100% ZEV sales by 2040, and these regulations have improved ZEV model availability. In 2019, approximately 37 ZEV models were offered in Canada.[102] With these mandates, pickup trucks, SUVs, sedans, and hatchbacks, including both two- and four-wheel drive options, became available as ZEVs and by 2023, more than 50 ZEV models were offered in Canada, with an announcement to launch additional 41 models by auto industry in 2024.[103]

- **Reducing Prices:** Competitive pressures from supply-side regulations lead to cost reductions in the ZEV market. In the UK, manufacturers have reduced ZEV prices by up to 11% as of 2023 to comply with ZEV regulations, with prices dropping for nearly 7 out of 10 models. In 2024, the OEMs provided substantial discount of over 10% on recommended retail price for top ten selling ZEV models in UK. At the start of 2024, the price of ZEV was 35% higher than equivalent ICE counterpart, however by 2025, with the ZEV regulations helping to bridge the gap between ICE vehicles and ZEVs, this price gap had narrowed to 24%.[104] Presently, there are 29 models of new electric cars priced under GBP 30,000 (USD 39,822) in the UK.[105]

- **Driving ZEV Sales:** In US, the implementation of ZEV regulations has significantly accelerated ZEV adoption. In 2024, 1.7 million electric cars were sold, marking a 21% increase compared to the 1.4 million units sold in 2023.[106] The combined sales share of BEVs and PHEVs in the light-duty vehicle (LDV) category reached approximately 12% in ZEV-regulated states (excluding California), double the 6% observed in non-ZEV states.[107] California led the way with the highest ZEV market share in 2023, achieving a sales share of 26.4%.[108] Notably, the states with ZEV programs formed a multi-state task force to collectively implement ZEV regulations and have achieved the target of having 3.3 million ZEVs on their roads by 2025.[109] The increase in ZEV sales indicate that supply-side regulations bring down the cost by providing market certainty. When manufacturers have certainty, they further invest in the production of ZEVs and thereby the costs reduce through economies of scale.

  Globally, regulatory measures have shown similar success. In the EU, after the introduction of CO_2 regulations, the market share of EVs in Europe jumped from 3% in 2019 to 22.7% in 2023.[110] Similarly, in China, the ZEV market share jumped from under 6% in 2019 to 52% in 2025 as the first two phases of the New Energy Vehicle (NEV) requirements came into effect.[111]

the government schemes initially kick-started the public charging markets in the US; however, eventually with rising ZEV sales, the private sector investments have increased to approximately USD 12.7 billion by 2023.

- **Mobilizing Investment in Charging Infrastructure:** By providing market certainty, ZEV regulations have driven substantial investments in ZEV charging infrastructure. For example, the government schemes initially kick-started the public charging markets in the US; however, eventually with rising ZEV sales, the private sector investments have increased to approximately USD 12.7 billion by 2023.[112] In California, the state that pioneered ZEV regulation in the US, there are 48% more ZEV chargers as compared to gasoline nozzles, reaching 178,000 ZEV chargers in 2024. Furthermore, the state has approved USD 1.4 billion investment plan to build an extensive ZEV charging and hydrogen network.[113] Similarly, owing to the record ZEV sales, the UK saw a 44% increase in the number of charging stations between 2023 and 2024, with an ambitious goal of installing 300,000 charging stations nationwide by 2030.[114] Nearly GBP 6 billion (USD 7.96 billion) of private funding will be invested in the UK's charge point roll-out by 2030.[115]

The Canada government has allocated over USD. 1.2 billion to support the deployment of over 43,000 chargers across the country, more than doubling the existing number of public charging stations.[116] Additionally, the private sector has planned major investments in the public charging network and it is expected that with high enough demand in urban centers and high traffic corridors, the ZEV charging business would be viable even without government support. Through the Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (EVAFIDI), Canada leveraged USD 2 of private capital for every USD 1 of government funding which resulted in a total investment of USD 260 million.

In the UK, manufacturers have reduced ZEV prices by up to 11% as of 2023 to comply with ZEV regulations, with prices dropping for nearly 7 out of 10 models.

- **Increasing Employment Opportunities:** The adoption of the Advanced Clean Cars II (ACC II) rule in California and other Section 177 states is projected to generate 300,000 new jobs by 2050.[117] According to government analysis, the UK's infrastructure network alone could support 12,000 full-time equivalent jobs per year by 2030. Additionally, over 8,000 jobs are expected to be created in the manufacturing and installation of charge points.[118]
- **Improved Health Benefits:** Research study estimates that the adoption of the ACC II standards across Section 177 states could reduce a cumulative of 1,310 million metric tons (MMT) of carbon dioxide-equivalent (CO_2e) pollutants by 2050. This is equivalent to GHG emissions from more than 282 million gasoline-powered vehicles driven over the period of one year. It is estimated that nearly 239 million ZEVs could be registered in US by 2050 and as a result the ACC II rule could prevent over 160,000 asthma attacks and 240,000 cases of bronchitis and respiratory symptoms in the coming decades. This reduction would also benefit marginalized and low-income communities, who are often disproportionately affected.[119]
- **Reduced need for government subsidies:** As ZEV sales requirements become more stringent over time, manufacturers increasingly enter the market and compete to gain market share by offering a wider range of models at competitive prices, thereby reducing the long-term need for government subsidies.[120] As more vehicle models become available in the market and due to economies of scale, there would eventually be a reduction in cost, ultimately leading to consumer benefit. This market-driven affordability reduces reliance on direct financial incentives or subsidies from the government.[121]

From the above examples, it is evident that ZEV regulations have enabled an increase in ZEV model availability, improved price parity between ICE vehicles and ZEVs, mobilized investments in ZEV charging infrastructure, increased employment opportunities and improved health benefits. However, it is equally important to delve into the underlying mechanism that helped these countries to operationalize ZEV regulations with the right set of risk-reward mechanisms. The supply-side regulations will also have implications on the exchequer account, while on one hand it will reduce the need for fiscal incentives but also signal a structural shift which could lead to significant changes in the government tax revenue from the ICE vehicles. The next section delves deeper into how governments have been operationalizing alternate revenue streams and restructuring existing revenue models to fund the ZEV transition.

1.5 Fiscal Transition in the Age of ZEVs: Rethinking Revenue Models

The adoption of the Advanced Clean Cars II (ACC II) rule in California and other Section 177 states is projected to generate 300,000 new jobs by 2050.

Governments across the world earn revenue from the sale and use of ICE vehicles through a range of instruments which include registration fees, motor vehicle tax, penalties for non-compliance with emission standards, fitness certification fee, emission test fee and fuel tax. These tax revenues, particularly in developing economies, not only help fund the maintenance of road infrastructure but also contribute towards other welfare schemes. While the transitions to ZEVs will lead to decrease in fuel tax and motor vehicle tax revenue, one should take into account that certain tax exemptions are provided to ZEVs in the transition phase only. Once the ZEV market matures, the government will reintroduce these instruments as they will also help the government to tackle issues around increasing vehicle ownership and congestion. However, there are measures that are implemented to complement supply-side regulations and a few alternate revenue streams that help the government to fund the ZEV transition.

France implemented its Bonus-Malus program since 2008 and it offers a bonus of EUR 6000 for new cars with zero CO_2 emissions while the bonus is EUR 1000 for cars with emissions up to 50 g/km. For cars emitting over 128 gCO_2/km, the malus tax ranges from EUR 50 to EUR 40,000.

- **Measures to complement Supply-Side Regulations:** While supply-side regulations help in accelerating ZEV adoption, there is a need for some complementary measures that can implemented to support the ZEV transition. These measures will also make owning an ICE vehicle expensive and thereby incentivize people to buy more ZEVs.

  Feebate mechanism or Bonus-malus programs: In the feebate mechanism, the ICE vehicles that emit tailpipe emissions are imposed fees/penalties, while the low-emission vehicles and ZEVs are provided with incentives. The fees make it expensive to own and operate conventional vehicles, while the incentives would make ZEVs more affordable. For example, France implemented its Bonus-Malus program since 2008 and it offers a bonus of EUR 6000 for new cars with zero CO_2 emissions while the bonus is EUR 1000 for cars with emissions up to 50 g/km. For cars emitting over 128 gCO_2/km, the malus tax ranges from EUR 50 to EUR 40,000.[122]

- **Reinstating Revenue Streams after the Transition Phase**: To kickstart ZEV adoption and overcome the initial barrier of high upfront purchase cost, governments waived off the registration fee and motor vehicle tax for ZEVs. Once the transition phase ended and the ZEV markets matured, there was a need to reinstate the registration fee and motor vehicle tax for ZEVs as this revenue stream was crucial for maintenance of road infrastructure.

  Registration Fee for ZEVs: In the US, 39 states have implemented special registration fee for ZEVs in addition to the traditional motor vehicle registration fees. The ZEV registration fees are in the range of USD 50 to USD 290. At least 9 states, including California, have structured the ZEV registration fees to grow over time by tying it to key inflation-related metrics.[123]

- **Alternate Revenue Streams**: Growing ZEV sales are generating alternate revenue streams for government to replace the revenue earned from ICE vehicle sales and use. Electricity tax and increased investments into ZEV and ancillary manufacturing are two main alternate streams of revenue from the ZEV industry.

Increasing Electricity Tax: To support ZEV adoption in the transition phase, many governments initially kept electricity taxes for charging minimal to encourage its uptake. However, as the ZEV markets matured, to expand the charging infrastructure network and support grid upgradation, the policymakers began imposing new taxes or increasing existing taxes on electricity consumption for ZEV charging. UK has imposed 20% value added tax (VAT) at public charging stations and 5% VAT for domestic electricity use.[124]

Investments in ZEVs and ancillary manufacturing: The supportive policies implemented across countries to increase ZEV adoption has attracted huge investments into ZEV and ancillary manufacturing of batteries and other components. These investments have generated a new source of revenue for the governments and helped create employment opportunities. Automakers across the globe have committed to invest USD 1.2 trillion into ZEV transition and this includes investment into ZEV and battery manufacturing to the tune of USD 346 billion in Europe, USD 312 billion in US and USD 243 billion to China.[125] In India, the investment commitments rose over three times in the past three years and investment of around USD 40 billion is expected over the next 5 to 6 years for the development of ZEVs and ancillary industries in the country.[126]

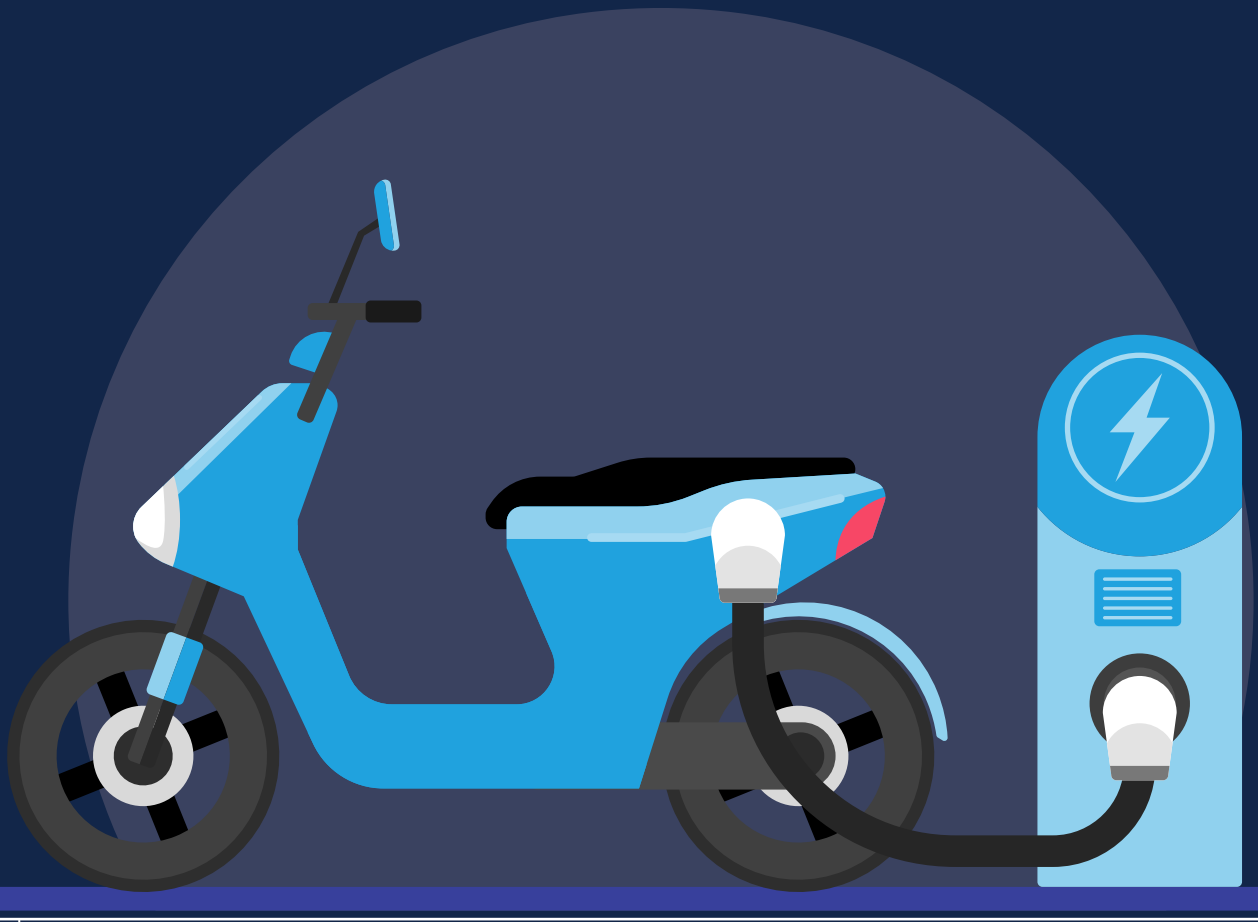
The revenue generated from the complementary measures and alternate revenue streams has enabled policymakers to develop more decisive supply-side regulations that can self-sustain the ZEV transition with minimal burden on the government exchequer. The design of these regulations has been contextualized to suit the economy, geography and cultural needs of the people residing in the target regions. The following chapter will delve deeper into the ZEV industry and its growth in India to provide a perspective on the need for enhanced supply-side regulations for the country.

Automakers across the globe have committed to invest USD 1.2 trillion into ZEV transition and this includes investment into ZEV and battery manufacturing to the tune of USD 346 billion in Europe, USD 312 billion in US and USD 243 billion to China.

Source: Freepik.com

2. ZEV Adoption in India: Conceptualizing Supply-Side Regulations

India's transport sector is a major contributor to energy consumption and emissions, accounting for 14% of energy-related CO2 emissions.[127] Within the sector, road transport alone contributes to 90% of these emissions, highlighting urgent need for decarbonization to reduce the harmful impacts of increasing air pollution.[128] Reflecting this trend, vehicle ownership in India more than doubled in past decade from 159 million in 2012 to over 354 million in 2022.[3] As India seeks to meet the growing demand for personal mobility and freight transport, energy use and CO_2 emissions from road transport are projected to double by 2050, unless robust interventions are put in place.[129] This trajectory threatens to undermine national climate goals and worsen air quality, especially in urban centers already bearing the brunt of pollution.[130]



The national government has employed a range of strategies, such as the Bharat Stage emissions standards and fuel efficiency standards, in order to decarbonize the road transport sector. Measures to increase ZEV uptake have also been provided, like demand incentives, such as Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME I & II), Electric Mobility Promotion Scheme (EMPS) and PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) to Production Linked Incentive (PLI) schemes to foster localized ZEV manufacturing ecosystem. The FAME scheme, launched in two phases starting in 2015, played a crucial role in encouraging ZEV adoption in India. The figure below provides a detailed timeline of the national and state-level schemes and policies to support ZEV adoption.

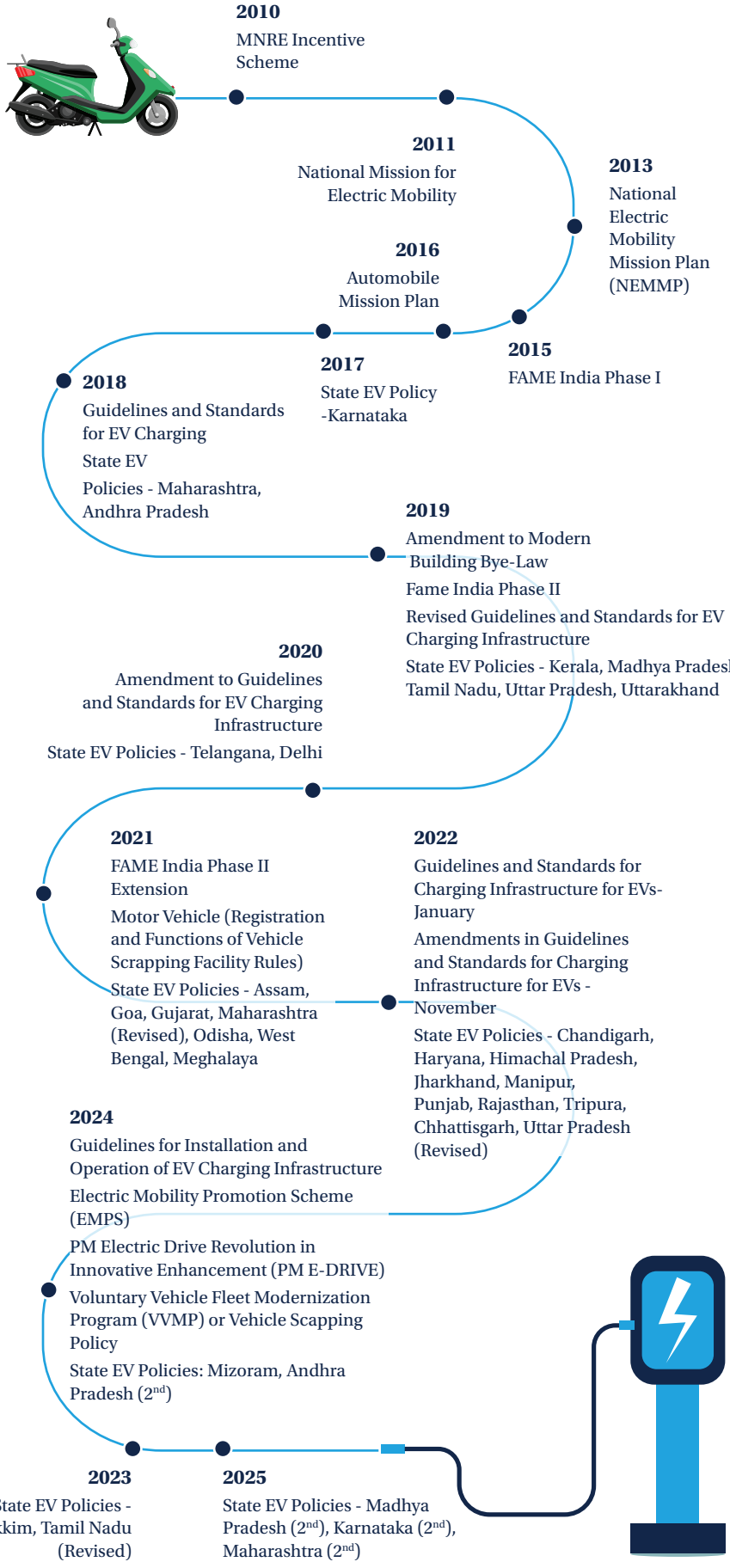
As a result of these initiatives, the ZEV sales exceeded 1.96 million units in the fiscal year 2024-25. This figure still represents only 7.49% of total vehicle sales, which stood at approximately 26.3 million during the same period.[131] While current policies and incentives are projected to enable 30-35% electrification of new vehicle sales by 2030, the International Energy Agency's 2023 report highlights the need for at least 50% ZEV adoption within the next decade to stay on track for the nation's 2070 net-zero target.[132] While demand incentives have been effective in kickstarting the ZEV adoption in India, this is an opportune time to complement the existing schemes/policies with supply-side regulations to accelerate the ZEV transition and pave the way for ZEV market maturity in the country.

The slow adoption of ZEVs can largely be attributed to higher upfront costs, a limited variety of ZEV models that match the performance of internal combustion engine vehicles, and a lack of widespread public charging infrastructure. To truly accelerate India's ZEV transition, addressing these challenges and ramping up supply-side efforts will be critical.

2.1 India's Automobile Industry and Need for Supply-Side Regulations

India's automobile industry plays a pivotal role in the country's economic landscape, contributing approximately 7.1% to India's GDP and around 49% to the manufacturing sector's GDP.[133] It also supports the livelihood of over 30 million people, with 4.2 million directly employed and 26.5 million in indirect jobs. The sector's export

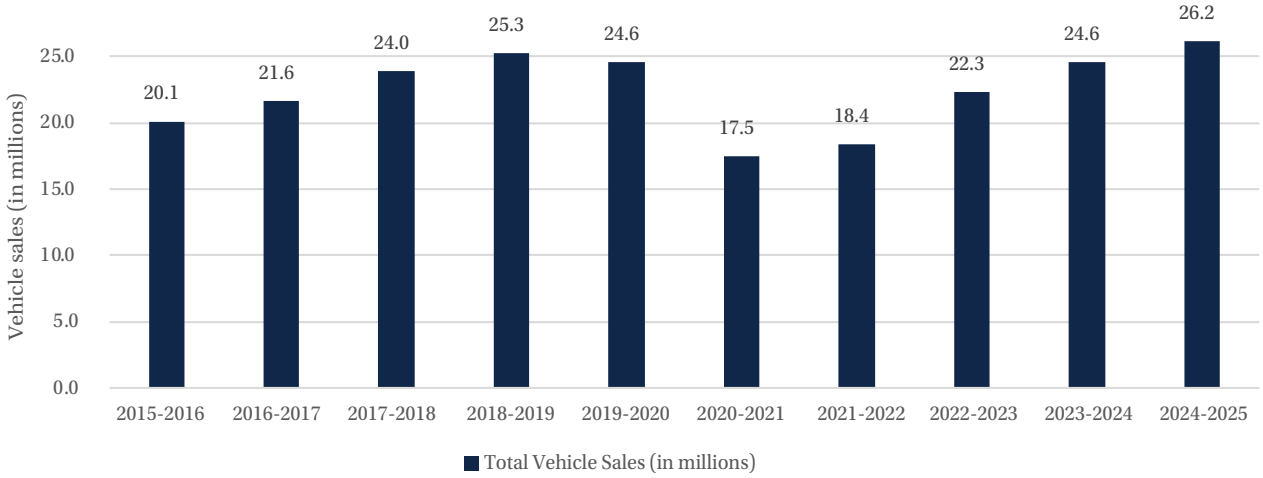
Figure 12: Timeline of Policy Interventions Supporting ZEV Adoption in India



Source: NRDC Analysis

strength is significant, with more than 4.5 million vehicles shipped to regions including Africa, Latin America, the Middle East, and South Asia.[134] India stands as a global leader in various segments of the automobile market, ranking among the top three producers of both passenger and commercial vehicles, while also being the largest market for two-wheelers and three-wheelers worldwide. Not only in the ICE vehicle segments, India also emerged as the world's largest electric three-wheeler market and the second-largest electric two-wheeler market, with respective sales of 580,000 and 880,000 units in 2023.[135]

Figure 13: Vehicle Sales in Million in India (FY 2015-16 to 2024-25)



Source: Vahan Dashboard

India's automobile industry was valued at USD 121.5 billion in 2021 and it is projected to reach USD 247.4 billion by 2033, growing at a CAGR of 7.3% during the forecast period of 2024-2033.[136] Industry's sales recorded a 6.5% increase in FY 2024-25, reaching an all-time high of 26.2 million units compared to 24.6 million units in FY 2023-24, as seen in the figure above.[6] This surge is driven by rising disposable incomes, urban expansion, e-commerce growth and infrastructure development. However, the resulting increase in vehicle ownership, has contributed to significant increase in fuel consumption in the transport sector.

The two-wheelers account for over 75% of petrol sales, nearly doubling over the past decade at CAGR of 8.1%. India imports over 87% fossil fuels and this has significantly contributed to the nation's growing import bill, raising concerns about energy security.

Fuel Consumption in Indian Transport Sector

The road transport sector accounts for almost 80% of high-speed diesel (HSD) and 99% of petrol consumption in India.[137] In FY 2023-24, the oil marketing companies (OMCs) sold 37.22 million tons of oil equivalent (Mtoe) of petrol, reflecting a 6.4% increase compared to FY 2022-23. This represents a record high, with a monthly average exceeding 3 Mtoe.[138] Fuel consumption overall surged to a record 233.3 million tones and despite stable domestic production at 29.4 million tones, India spent USD 132.4 billion on crude imports. Notably, the two-wheelers account for over 75% of petrol sales, nearly doubling over the past decade at CAGR of 8.1%.[139] India imports over 87% fossil fuels and this has significantly contributed to the nation's growing import bill, raising concerns about energy security.

To reduce India's oil dependency and achieve decarbonization of transport, the central government has taken measures to reduce the fuel consumption and emissions from ICE vehicles. Bharat Stage (BS) standards and the Corporate Average Fuel Economy (CAFE) standards have played a key role in reducing the tailpipe emissions and producing more energy efficient vehicles in India.

2.2 Existing Supply-Side Interventions in India

With growing vehicle ownership, the transport sector accounted for 14% of energy-related CO_2 emissions in India and it is the third most greenhouse gas (GHG) emitting sector. Road transport accounts for 87% of passenger traffic and 60% of freight movement in the country, driving emissions in the transport sector with fossil fuel consumption.[140] To address the rising emissions caused by the transportation sector, the Indian government introduced emission standards as early as 1989 followed by introduction of Bharat Stage (BS) emission norms later in 2000. These regulations have evolved since then and progressively gotten stricter to curb vehicular pollution. In 2015, India further strengthened its regulations by introducing Corporate Average Fuel Economy Standards (CAFE), which aim at emission reduction along with fuel efficiency.

2.2.1 Bharat Standard Standards: Reducing Emissions Across Vehicle Segments

India's Bharat Stage Standards (BS) standards followed Euro standards, beginning with the introduction of the India 2000 standard, which was aligned with Euro 1 norms. This was followed by the Bharat Stage II (BS II) standards, BS III, BS IV and then India leapfrogged the BS V norms, due to widespread concern raised over deteriorating air quality in the country and implemented the BS VI standards nationwide in 2020. Over time, these norms have become increasingly stringent for different types of tailpipe emissions. Previously, particulate matter (PM) emissions regulation applied to only diesel vehicles. However, under the BS VI standards, both petrol and diesel vehicles across all categories are now required to comply with PM emission standards. The figure below depicts the evolution of BS standards in India over time.[141]

Figure 14. Evolution of Bharat Standards in India (2000-2020)

2000
Bharat Standards
Equivalent to Euro 1
Application to passenger cars, two-wheelers, commercial buses and trucks

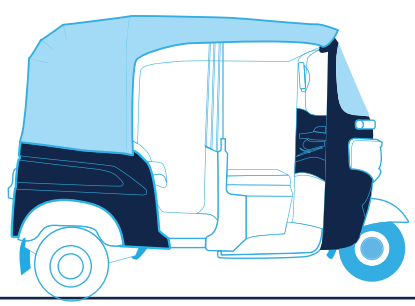
2005
Bharat Standards II
Equivalent to Euro 2
Mandatory catalyctic converter for petrol vehicles, stricter emission limits
Applicable to same vehicle segment as BS I

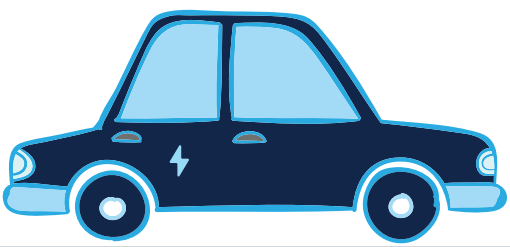
2010
Bharat Standards III
Equivalent to Euro 3
Mandate to reduce sulfur content (350 ppm) in fuel (petrol & diesel)
Applicable to cars, two & three-wheelers, LCVs, and HCVs

2017
Bharat Standards IV
Equivalent to Euro 4
Mandate to lower sulfer content (50ppm) in fuel introduction of exhaust treatment technology
Applicable to the same vehicle segment as BS III

2020
Bharat Standards VI
Equivalent to Euro 6
Mandate to lower sulfer content (10ppm) in fuel
Requirement to measure RDE (Real Driving Emission test)
Applicable to all vehicle types

Source: NRDC Analysis





Due to the implementation of CAFE I and CAFE II standards, the limit for CO_2 emissions has reduced by 24% from over 150g CO_2/km to 113g CO_2/km between 2006 and 2022.

The decrease in carbon monoxide emissions has been significant in the three-wheeler and four-wheeler category from BS I to BS VI while reduction in hydrocarbons and nitrogen oxide emissions is greater in the two-wheeler category. While Bharat standard regulations played a crucial role in vehicular emission reduction, there was a growing need to improve fuel efficiency and regulate carbon dioxide emissions. Therefore, the Corporate Average Fuel Efficiency (CAFE) norms were introduced to complement the BS standards.

2.2.2 Corporate Average Fuel Efficiency (CAFE) Norms: Increasing Fuel Efficiency of Passenger Cars

The BS standards were introduced for two-wheeler, three-wheeler and four-wheeler vehicles used for passenger and goods transportation, including heavy-duty vehicles with GVW above 3,500 kg. Considering the market dynamics, data availability and potential for significant impact on fuel consumption and emissions, the CAFE norms, by the Bureau of Energy Efficiency (BEE), were specifically introduced for passenger cars (M1 category) with a GVW of less than 3,500 kg only. The first phase, CAFE I, was implemented from FY 2017–18 to FY 2021-22, and the CAFE II came into force from FY 2022–23.[142] The CAFE norms set threshold limits for the kerb weight, fuel consumption (litres/100 km) and the average CO_2 emissions (gCO_2/km). Due to the implementation of CAFE I and CAFE II standards, the limit for CO_2 emissions has reduced by 24% from over 150g CO_2/km to 113g CO_2/km between 2006 and 2022.[143]

Building on these regulations, draft proposals for CAFE III and CAFE IV have been introduced, covering the periods from 2027 to 2032 and 2032 to 2037, respectively, to further enhance fuel efficiency and reduce emissions in the automotive sector. BEE has proposed changes to the type approval process, shifting from the MIDC cycle to the Worldwide Harmonized Light vehicles Test Procedure (WLTP) cycle under CAFE III standards.[144] While the MIDC is testing procedure to measure the emissions and fuel consumption in Indian vehicles, WLTP is a global standard to measure fuel consumption, CO_2 emissions and pollutants in a wide range of vehicles including fully electric vehicles. WLTP is designed to be more representative of the real-world driving conditions including a wider range of speeds, accelerations and braking points.[145]

Following this national-level rule on vehicle scrapping, 18 states/union territories have notified their respective vehicle scrapping policies.

To optimize compliance costs and promote innovation, the regulations incorporate flexibility mechanisms. One such mechanism is the use of "super credits," which incentivize manufacturers to produce and sell battery electric vehicles (BEVs). These credits allow manufacturers to earn additional emission allowances, which can be used to offset the emissions of ICE vehicles within their fleet.[146] Higher credits are granted for BEVs and FCEVs, while credits for PHEVs and strong Hybrid Electric Vehicles (HEVs) have been reduced. This mechanism is designed to accelerate the adoption of BEVs and FCEVs, ensuring a faster transition to ZEVs.

As per the data made public by BEE, all the eligible manufacturers have maintained 100% compliance with CAFE I norms and it is to be seen if 100% compliance will be achieved under CAFE II as well.[147] Parallel to the national government's supply-side regulations, state governments have also implemented several initiatives to accelerate the transition to cleaner mobility. These include setting timelines to phase out operational ICE vehicles, operationalizing vehicle scrappage policy and establishing specific goals for ZEV penetration within their jurisdictions, which are discussed in detail in the next section.

2.2.3 State Efforts to Decarbonize Road Transport

Along with the national-level policies, many states have also implemented both demand-side and supply-side interventions to support the ZEV transition. Twenty-seven Indian states and Union Territories have implemented ZEV policies, while two more remain in the draft stage. These policies encompass a mix of fiscal and non-fiscal measures, including upfront subsidies, tax exemptions, and the development of charging infrastructure, aimed at fostering a robust ZEV ecosystem. One of the key national policies that would help in retiring old ICE vehicles is the notification of the Motor Vehicles (Registrations and Functions of Vehicle Scrapping Facility) Rules, 2021 and its implementation is under the prerogative power of the respective state. Following this national-level rule on vehicle scrapping, 18 states/union territories have notified their respective vehicle scrapping policies.[148]

The Government of India recently launched the Voluntary Vehicle Fleet Modernization Program (VVMP) or Vehicle Scrapping Policy in 2024, which introduces a system of incentives and disincentives to create an ecosystem for phasing out old, polluting vehicles. This program offers various concessions on vehicle prices and taxes for owners who choose to scrap their old vehicles and to discourage the re-registration of older vehicles, the program has increased fees for fitness tests and re-registration. This dual approach aims to make it expensive to own and use old ICE vehicles.[149] For example, Delhi has introduced different benefit slabs for vehicle scrapping, with higher incentives offered for vehicles that are replaced by more efficient and less-polluting fuel technologies, such as CNG and petrol, as compared to diesel vehicles.[150]

Another proactive measure implemented by the state governments is to phase out old ICE vehicles. This includes prohibition on the operation of diesel vehicles older than 10 years and petrol vehicles older than 15 years.[151] The regulations involve measures such as prohibiting re-registration of these vehicles and restriction on fuel stations that would supply fuel to these vehicles.[152] End-of-life vehicles (ELVs) in some regions of Delhi NCR account for approximately 20% of all registered vehicles, with over 4.2 lakh ELVs, of which 1,29,000 are diesel vehicles with higher emission levels.[153] With an intent to address critical issues such as rising air pollution and respiratory ailments, Delhi was the first to introduce goals for phasing out ICE vehicles in 2021, which were implemented in the state starting from January 1, 2022. This initiative also inspired other states, such as Maharashtra and Madhya Pradesh, to consider similar measures to phase out ICE vehicles.

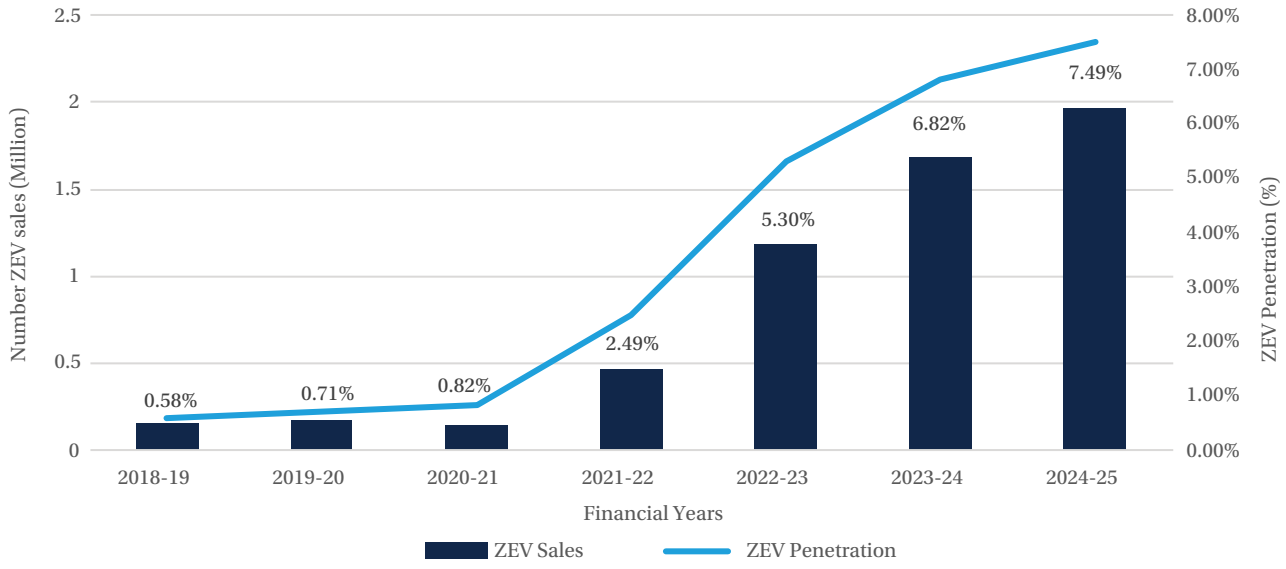
To effectively phase out ICE vehicles, it is important to holistically develop a ZEV ecosystem which can replace the ICE vehicles in India. The ZEV transition in India began with a focus on battery electric vehicles and the the government of India has taken significant measures to initiate ZEV adoption in the country. The following section delves deeper into the growth of ZEVs in India and analyses the OEM-wise ZEV sales to identify the opportunity for India to design and implement innovative supply-side regulations. In the following section, the ZEV sales refers only to the sale of BEVs, given that there are no fuel cell electric vehicles (FCEVs) available for sale in India.

The ZEV sales in India have surged from 0.14 million to 1.96 million over the last six financial years, reflecting a remarkable CAGR of 50.39%. While the ZEV penetration in India was around 7.49% for FY 2024-25, the country has set a goal of achieving 30% ZEV penetration in new vehicle sales by 2030.

2.3 Growth of ZEV Sales in India

The ZEV sales in India surged from 0.14 million to 1.96 million over the last six financial years, reflecting a remarkable CAGR of 50.39%.[6] While the ZEV penetration in India was around 7.49% for FY 2024-25, the country has set a goal of achieving 30% ZEV penetration in new vehicle sales by 2030. According to NITI Aayog, to achieve this goal, the individual vehicle segments must reach an estimated ZEV penetration of 80% for two- and three-wheelers, 30% in private cars, 70% in commercial vehicles and 40% in buses.[154]

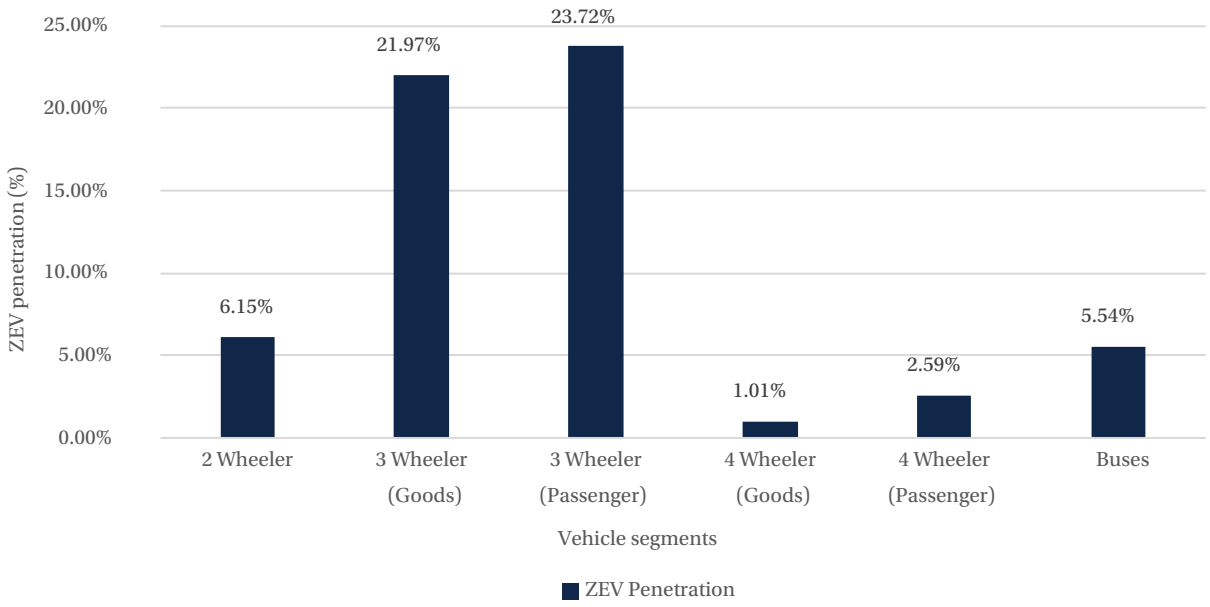
Figure 15: ZEV Sales and ZEV Penetration Growth in India (FY 2018-19 to FY 2024-25)



*Note: Here, ZEV includes Battery Electric Vehicles only.
Source: Vahan Dashboard

However, with less than five years remaining to reach the 2030 goal, ZEV penetration in each segment is yet to reach the halfway mark. The ZEV penetration for FY 2024-25 remains under 10% in all vehicle segments, except for the three-wheelers, as shown in the figure below.[6]

Figure 16. ZEV Penetration Rate in Different Vehicle Segments (FY 2024-25)



*Note: Here, ZEV includes Battery Electric Vehicles only.

Source: Vahan Dashboard

The e-2W and e-3W account for 54% (3.08 million) and 42% (2.3 million) of total (5.7 million) ZEV sales, respectively. In contrast, electric car sales were limited to only 80,000 units, representing less than 2% of all cars sold.

Considering India's vehicle ownership ownership patterns and availability of affordable ZEV models in the categories of two-wheelers and three-wheelers, the e-2W and e-3W account for 54% (3.08 million) and 42% (2.3 million) of total (5.7 million) ZEV sales, respectively. In contrast, electric car sales were limited to only 80,000 units, representing less than 2% of all cars sold. The ZEV penetration across vehicle segments indicates that certain vehicle categories, such as two-wheelers and three-wheelers, are transitioning to ZEVs at a faster pace due to favourable total cost of ownership (TCO), as compared to other vehicle segments. Therefore, it is essential to analyse OEM's vehicle sales across vehicle segments to provide better visibility on which vehicle segments are ready and which other vehicle segments would require more lead time for the implementation of supply-side regulations.

2.3.1 ZEV Adoption and Market Dynamics in India

In this section, the vehicle sales across the top ten OEMs indicate the market share of each OEM and its respective ZEV sales in the respective vehicle category. It is observed that, except in the category of passenger cars, new-age OEMs with 100% ZEV manufacturing and sales have entered the top 10 list in other vehicle categories.[6]

Two Wheelers:

India's vehicle sales are dominated by two-wheelers, and they account for more than 70% of total vehicle sales in the country. Over 18.7 million two-wheelers were sold in India in FY 2024-25 with 6.15% ZEV penetration in this category. India's electric two-wheeler market, currently valued at USD 1.6 billion (FY 2024-25), is expected to grow at a CAGR of 28.34% between FY 2025 and FY 2032.[155] The price gap between the ZEV models and ICE vehicles in the two-wheeler segment is narrowing and the TCO of e-2W is over 50% lower than its ICE counterpart which has led to increasing adoption of e-2W in the e-commerce and logistics sector, as well as for personal use.[156]

- Among all two-wheeler OEMs in India the top two OEMs, Hero MotoCorp Ltd and Honda Pvt Ltd lead the market, with sales shares of 29.15% and 25.61%, respectively. However, in FY 2024-25, their ZEV sales penetration was less than 1%.

- TVS and Bajaj have made significant progress in the ZEV sector, selling 17.72% and 11.52% of ZEVs out of their total vehicle sales, respectively.
- OLA and Ather Energy specialize solely in electric vehicles, holding market shares of 1.84% and 0.70%, respectively.[6]

Table 3: ZEV and ICE Sales by Two-Wheeler OEMs in FY 2024-25

Two-Wheeler Sales in India (FY 2024-25)						
Sl. No.	Maker	ZEVs	ICE	Total	% Market Share	ZEV Sales as % of total vehicle sales by OEM
1	Hero MotoCorp Ltd	48,703	5,402,866	5,451,569	29.15%	0.89%
2	Honda Motorcycle and Scooter India (P) Ltd	199	4,790,683	4,790,882	25.61%	0.00%
3	TVS Motor Company Ltd	237,703	3,077,514	3,315,217	17.72%	7.17%
4	Bajaj Auto Ltd	231,002	1,923,914	2,154,916	11.52%	10.72%
5	Suzuki Motorcycle India Pvt Ltd	0	982,479	982,479	5.25%	0.00%
6	Royal-Enfield (Unit of Eicher Ltd)	0	844,078	844,078	4.51%	0.00%
7	India Yamaha Motor Pvt Ltd	0	650,042	650,042	3.48%	0.00%
8	Ola Electric Technologies Pvt Ltd	344,052	0	344,052	1.84%	100.00%
9	Ather Energy Pvt Ltd	131,048	0	131,048	0.70%	100.00%
10	Greaves Electric Mobility Pvt Ltd	40,162	0	40,162	0.21%	100.00%
11	Others	117,081	79,896	196,977	1.05%	59.44%
	Total	**1,149,950**	**17,751,472**	**18,704,445**	**100%**	**6.15%**

**Note: Here, ZEV includes Battery Electric Vehicles only.*

Source: Vahan Dashboard

With more affordable e-2W models entering the Indian market, this vehicle segment dominates ZEV sales in India. Given the attractive TCO and high volume of ZEV sales, the e-2W category is well-positioned for the implementation of supply-side regulations with a lesser lead time.

Three-Wheeler Passenger Vehicle:

Nearly 9.32 million auto-rickshaws are registered in India, doubling from 4.8 million in 2010, accounting for approximately 25% of all urban trips in the country.[157] Passenger auto-rickshaws play a crucial role in enabling first and last-mile connectivity, thereby supporting the use of public transportation in the country. India has become the global leader in the three-wheeler market, with established manufacturers like Bajaj Auto, Mahindra, and Piaggio at the forefront of production.[148] In the financial year 2024-25, the three-wheeler passenger segment recorded total sales of 0.56 million units, with the highest segment-wise ZEV penetration of 23.72%. Over 94% of the total sales and over 86% of the ZEV sales are distributed among the top 4 OEMs in this category.

In the financial year 2024-25, the three-wheeler passenger segment recorded total sales of 0.56 million units, with the highest segment-wise ZEV penetration of 23.72%.

- Bajaj Auto Ltd dominated the market with a share of 68.82% and Piaggio Vehicles Pvt Ltd follows closely as the second-largest player in this segment.
- Mahindra, which holds a total sales share of 9.99% in this segment, has made impressive progress by achieving an ZEV penetration rate of 93.35%.
- TI Clean Mobility Pvt Ltd and Omega Seiki Pvt Ltd are the two OEMs with 100% ZEV sales in this category.[6]

Table 4: ZEV and ICE Sales by Three-Wheeler (Passenger Rickshaw) OEMs in FY 2024-25

Three-Wheeler Passenger Rickshaw Sales in India (FY 2024-25)						
Sl. No.	Maker	ZEVs	ICE	Total	% Market Share	ZEV Sales as % of total vehicle sales by OEM
1	Bajaj Auto Ltd	46,067	337746	383,813	68.82%	12.00%
2	Piaggio Vehicles Pvt Ltd	16,535	44781	61,316	10.99%	26.97%
3	Mahindra	51,997	3,707	55,704	9.99%	93.35%
4	TVS Motor Company Ltd	1,692	23749	25,441	4.56%	6.65%
5	Atul Auto Ltd	780	9023	9,803	1.76%	7.96%
6	TI Clean Mobility Pvt Ltd	6,088	0	6,088	1.09%	100.00%
7	MLR Auto Ltd	368	4208	4,576	0.82%	8.04%
8	Omega Seiki Pvt Ltd	2,511	0	2,511	0.45%	100.00%
9	Baxy Ltd	194	1193	1,387	0.25%	13.99%
10	Atul Greentech Private Limited	969	0	969	0.17%	100.00%
11	Others	5,084	1005	6,089	1.09%	83.49%
	Total	**132,285**	**425,412**	**557,697**	**100%**	**23.72%**

**Note: Here, ZEV includes Battery Electric Vehicles only.*

Source: Vahan Dashboard

As passenger auto-rickshaws travel a daily distance of more than 100 km, the fuel cost savings from driving an electric auto-rickshaw significantly offset the high upfront cost. With all the top 10 OEMs offering ZEV models, the electric passenger rickshaw segment can achieve accelerated ZEV penetration rate with the right supply-side regulations in a short period.

Three-Wheeler Goods Vehicle:

The three-wheeler goods segment is experiencing a rapid growth in the ZEV industry due to increase in demand from the e-commerce and logistics sector. In FY 2024-25, a total of 0.12 million three-wheeler goods vehicles were sold, achieving an ZEV penetration of nearly 21.97%.

- Leading OEMs like Bajaj Auto Ltd and Piaggio Vehicles Pvt Ltd, captured 43.55% and 22.74% of the market share, respectively, followed by Atul Auto Ltd and Mahindra Last Mile Mobility Ltd.
- Mahindra Last Mile Mobility Ltd has emerged as a leader in ZEV sales, with 62.34% ZEV penetration by selling over 7,000 ZEV units.
- Omega Seiki Pvt Ltd and Euler Motors Pvt Ltd, hold 2.86% and 2.45% of the market share, respectively, with 100% ZEV sales.[6]

Table 5: ZEV and ICE Sales by Three-Wheeler (Goods Vehicles) OEMs in FY 2024-25

Three-Wheeler Goods Vehicle Sales in India (FY 2024-25)						
Sl. No.	Maker	ZEVs	ICE	Total	% Market Share	ZEV Sales as % of total vehicle sales by OEM
1	Bajaj Auto Ltd	4,713	48,689	53,402	43.55%	8.83%
2	Piaggio Vehicles Pvt Ltd	1,922	25,964	27,886	22.74%	6.89%
3	Atul Auto Ltd	1,131	11,976	13,107	10.69%	8.63%
4	Mahindra Last Mile Mobility Ltd	7,032	4,248	11,280	9.20%	62.34%
5	Omega Seiki Pvt Ltd	3,504	0	3,504	2.86%	100.00%
6	Euler Motors Pvt Ltd	3,004	0	3,004	2.45%	100.00%
7	MLR Auto Ltd	59	1,542	1,601	1.31%	3.69%
8	Baxy Ltd	18	1,223	1,241	1.01%	1.45%
9	Capital Auto Industries	0	1,206	1,206	0.98%	0.00%
10	E Royce Motors India Pvt Ltd	1,060	0	1,060	0.86%	100.00%
11	Others	4,503	831	5,334	4.35%	84.42%
	Total	26,946	95,679	122,625	100%	21.97%

**Note: Here, ZEV includes Battery Electric Vehicles only.*

Source: Vahan Dashboard

Increasingly affordable ZEV models with fixed and swappable batteries are available in the Indian market, bridging the gap between the upfront cost of ZEVs and their ICE counterparts. Therefore, the e-3W goods vehicle segment is well-placed for the implementation of supply-side regulations.

Four-Wheeler Passenger Vehicle (Cabs and Cars):

Over 4 million passenger cars were sold in India in FY 2024-25, with a relatively low ZEV penetration rate of 2.6%. In personal use cases, the relatively low daily driving distances lead to lower savings in operating costs that are not enough to offset the higher upfront purchase costs of ZEVs. Whereas in fleets, the e-4Ws clock approximately 180 km per day which lead to increased operational savings, thereby presenting a favorable TCO.

With growing aspirations, car ownership in India is steadily increasing. Specifically, the electric car market in India is estimated at 3.31 billion USD in 2025 and is expected to reach 14.79 billion USD by 2029, growing at a CAGR of 45.44% during the forecast period (2025-2029).[158]

- Maruti Suzuki India Ltd led with the largest market share of 40.54%, followed by Hyundai Motor India Ltd, Tata Motors, and Mahindra.
- Maruti Suzuki India Ltd did not report any ZEV sales in FY 2024-25, while Hyundai Motor India Ltd sold 2,440 ZEVs, accounting for 0.44% of their total vehicle sales.
- Tata Motors and Mahindra have made notable progress, with ZEV penetration rate of 11.02% and 1.63%, respectively.
- MG Motor India Pvt Ltd, saw a significant share of ZEV sales, with 52.67% of their total sales being electric vehicles, which equates to approximately 30,297 ZEV units.[6]

Table 6: ZEV and ICE Sales by Four-Wheeler (Passenger Cars) OEMs in FY 2024-25

Four-Wheeler Passenger Car Sales in India (FY 2024-25)						
Sl. No.	Maker	ZEVs	ICE	Total	% Market Share	ZEV Sales as % of total vehicle sales by OEM
1	Maruti Suzuki India Ltd	0	1,671,187	1,671,187	40.54%	0.00%
2	Hyundai Motor India Ltd	2,440	557,121	559,561	13.57%	0.44%
3	Tata Motors	57,728	466,107	523,835	12.71%	11.02%
4	Mahindra	8,280	499,477	507,757	12.32%	1.63%
5	Toyota Kirloskar Motor Pvt Ltd	0	264,614	264,614	6.42%	0.00%
6	Kia India Private Limited	416	241,728	242,144	5.87%	0.17%
7	Skoda	1	83,932	83,933	2.04%	0.00%
8	Honda Cars India Ltd	0	64,784	64,784	1.57%	0.00%
9	MG Motor India Pvt Ltd	30,297	27,225	57,522	1.40%	52.67%
10	Renault India Pvt Ltd	0	38,580	38,580	0.94%	0.00%
11	Others	7,513	100,834	108,347	2.63%	6.93%
	Total	**106,675**	**4,015,589**	**4,122,264**	**100%**	**2.59%**

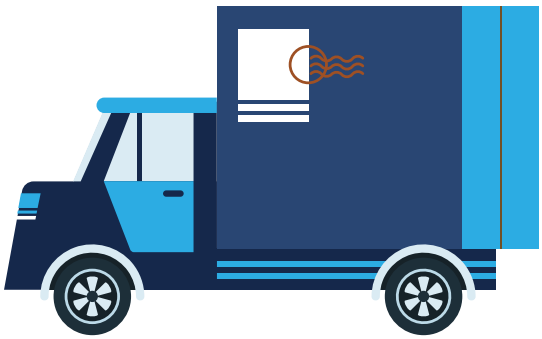
**Note: Here, ZEV includes Battery Electric Vehicles only.*

Source: Vahan Dashboard

Recently, there are new emerging business models for e-cars in the form of battery-as-a-service (BaaS) program where the e-car could be purchased at a lower upfront cost and the customer could pay separately for the battery on a pay-per-usage basis. Given that there are new affordable ZEV models entering the market in the e-4W segment, there are more definitive measures required to accelerate the ZEV adoption in this category which can lead to increased investment in ZEV manufacturing and development of charging infrastructure.

Four-Wheeler Goods Vehicle (only LCV):

Nearly two-thirds of the goods vehicles sold in India are light commercial vehicles (LCV) with GVW between 3.5 to 7 tons. With stricter restrictions on medium- and heavy-duty vehicles within city limits, the demand for LCVs in cities is increasing with the demand further boosted by growth in e-commerce and logistics sector. About 0.5 million LCVs were sold in FY 2024-25 but the ZEV penetration in this segment has been the lowest at 1.01%. It is estimated that the ZEV penetration in LCV segment is expected to increase to 15% by 2030.[159]



- Mahindra & Mahindra Ltd and Tata Motors dominate with market shares of 48.30% and 30.10%, respectively, followed by Ashok Leyland Ltd with 11.10%.
- OEMs like Tata Motors and Mahindra & Mahindra Ltd have made modest strides, achieving 2.11% and 0.35% ZEV sales, respectively, out of their total vehicle sales.
- Switch Mobility Automotive Ltd stands out as the only electric OEM in the top 10 by market share, having sold 100% ZEVs in FY 2024-25. [6]

Table 7: ZEV and ICE Sales by Four-Wheeler (Light Goods Vehicles) OEMs in FY 2024-25

Four-Wheeler Light Goods Vehicle Sales in India (FY 2024-25)						
Sl. No.	Maker	ZEVs	ICE	Total	%Market Share	ZEV Sales as % of total vehicle sales by OEM
1	Mahindra	854	244,538	245,392	48.2%	0.35%
2	Tata Motors	3,222	149,511	152,733	30.0%	2.11%
	Ashok Leyland Ltd (Including Switch Mobility)	445	56,573	57,018	11.2%	0.78%
4	Maruti Suzuki India Ltd	0	39,404	39,404	7.7%	0.00%
5	VE Commercial Vehicles Ltd	80	9,728	9,808	1.9%	0.82%
6	Isuzu Motors India Pvt Ltd	0	1,568	1,568	0.3%	0.00%
7	SML Isuzu Ltd	0	1,444	1,444	0.3%	0.00%
8	Force Motors Limited	0	578	578	0.1%	0.00%
9	Omega Seiki Pvt Ltd	122	0	122	0.0%	100.00%
10	Jaidka Power System PVT LTD	114	0	114	0.0%	100.00%
11	**Others**	299	164	463	0.1%	64.58%
	Total	**5,136**	**503,508**	**508,644**	**100%**	**1.01%**

**Note: Here, ZEV includes Battery Electric Vehicles only.*

Source: Vahan Dashboard

The major OEMs in this vehicle category have launched very limited ZEV models in the market and the ZEV market in this segment is yet to mature given the challenges with limited charging and battery swapping infrastructure. While the TCO is favorable, the OEMs are yet to increase their ZEV model offerings to create a competitive e-4W LCV market. Therefore, this vehicle segment requires a longer lead time for the implementation of binding supply-side regulations.

In India, over 90% of buses are privately owned and the rest are owned by state transport undertakings (STUs). Over 59,000 buses were sold in India in FY 2024-25 with an EV penetration of 5.54%.

Buses:

In India, over 90% of buses are privately owned and the rest are owned by state transport undertakings (STUs). Over 59,000 buses were sold in India in FY 2024-25 with an ZEV penetration of 5.54%. The electric bus market in India is estimated at 1.17 billion USD in 2025 and is expected to reach 2.48 billion USD by 2029, growing at a CAGR of 20.66% during the forecast period (2025-2029).[160] The various demand incentive schemes at the national-level, such as FAME I & II and PM E-DRIVE, only provided incentives for e-buses purchased for STUs. Recently, the National Electric Bus Program (NEBP) was launched with a target of deploying 50,000 e-buses by 2027 with an investment of USD 820 billion.[161] While demand aggregation and fiscal incentives have spurred the e-bus market for the STUs, electrification of private buses is yet to gain traction. While STUs across the country have announced 100% electrification goals, challenges such as high upfront costs, lack of charging infrastructure and high cost of finance are plaguing the debt-ridden STUs and the private sector.

- In FY 2024-25, Ashok Leyland and Tata Motors Ltd led the Indian bus sales market, each holding a 31% share, followed by VE Commercial Vehicles Ltd. with 20.72%. Among these top OEMs, Tata Motors Ltd sold 5.66% electric buses out of their total bus sales.
- Olectra Greentech Ltd. exclusively sold electric buses, capturing 1.18% of the market share.

Table 8: ZEV and ICE Sales by Bus OEMs in FY 2024-25

Bus Sales in India (FY 2024-25)						
Sl. No.	Maker	ZEVs	ICE	Total	%Market Share	ZEV Sales as % of total vehicle sales by OEM
1	Tata Motors Ltd	1,058	17,641	18,699	31.20%	5.66%
2	Ashok Leyland Ltd (Including Switch Mobility)	414	18,603	19,017	31.74%	2.18%
3	VE Commercial Vehicles Ltd	72	12,342	12,414	20.72%	0.58%
4	SML Isuzu Ltd	0	3,462	3,462	5.78%	0.00%
5	Daimler India Commercial Vehicles Pvt. Ltd	0	1,735	1,735	2.90%	0.00%
6	Mahindra & Mahindra Limited	0	1,231	1,231	2.05%	0.00%
7	Force Motors Limited	0	1,006	1,006	1.68%	0.00%
8	Olectra Greentech Ltd	710	0	710	1.18%	100%
9	VE Commercial Vehicles Ltd (Volvo Buses Division)	0	575	575	0.96%	0.00%
10	PMI Electro Mobility Solutions Private Limited	482	0	482	0.80%	100%
11	Others	582	11	593	0.99%	98.91%
	Total	**3,318**	**56,606**	**59,924**	**100%**	**5.54%**

**Note: Here, ZEV includes Battery Electric Vehicles only.*
Source: Vahan Dashboard

To enable the holistic decarbonization of the bus segment, there is a need to enable low-cost financing for e-buses so that the private sector can also see an uptick in ZEV adoption. The e-bus segment is still in its nascent stages in India, and measures are needed to reduce the upfront purchase cost and develop sufficient charging infrastructure to enable the transition to ZEVs in the bus category.

The analysis of OEM-wise sales in each vehicle category has provided deep insights into the level of preparedness for implementation of supply-side regulations. With this knowledge, the next section proposes a supply-side regulation that could be operationalized through a credit-based mechanism to accelerate ZEV adoption in India.

2.4 Conceptualizing Supply-Side Regulation for ZEV Transition in India

The Bharat Stage standards and the CAFE norms have been instrumental in improving the fuel economy and reducing emissions in ICE vehicles. However, to accelerate ZEV sales in India, there is a need to complement the demand incentives with different supply-side regulations. As seen in Section 1.3, the ZEV sales requirements were enforced to complement the existing performance-based supply-side regulations to accelerate ZEV sales. From the global case studies, we can observe that the supply-side regulations can play a crucial role in increasing the availability and affordability of ZEV models across vehicle segments, which are essential for increasing ZEV adoption.

In this report, we have two primary recommendations: 1) **developing a supply-side regulation** and 2) **enacting a ZEV sales-based credit mechanism** to operationalize this regulation. This ZEV regulation could be designed at the state level based on the vehicle ownership pattern and automobile manufacturing capability of the state. A designated nodal agency could be appointed to oversee the implementation of this regulation. Each automobile manufacturer in the country could be provided with an annual ZEV requirement that must be fulfilled for each financial year.

The tailored approach for for implementing the ZEV regulation for India is detailed below. This approach proposes proposes a risk-reward mechanism which is contextualized for India, making it more streamlined and simplified to enable ease of implementation.

- **Lead Time for Implementation**: It is important to give enough lead time for the automobile industry to ramp up their manufacturing facilities and prepare their dealerships to increase ZEV sales. For example, California adopted the ACC I program in 2012 and enforced it from 2018 while ACC II was adopted in 2022, and it will come into force from 2026. A lead time of 6 years and later 4 years were provided to prepare the industry for the ZEV transition. As seen in Section 2.3.1, certain vehicle segments are more ready than the others for this ZEV regulation. It is crucial to consider the different levels of readiness across vehicle segments as we design the supply-side regulation. Therefore, for India, a lead time of 3 to 8

years could be considered, based on the vehicle segment, before the implementation of the ZEV regulation on the vehicle manufacturers.

- **Categorization of Vehicle Manufacturers**: The number of vehicles manufactured or imported into India for sale could range from a few hundred to a million depending on the vehicle type, therefore it is important to categorize the manufacturers into small, medium and large manufacturers. The manufacturers can be assigned to the appropriate category by calculating the average of number of vehicles sold by the OEM in three consecutive fiscal years prior to the reporting period of the ZEV regulation.

- **Setting Eligibility Criteria for ZEVs**: The eligibility criteria for ZEVs will be based on the range and the level of localization. In order to ensure that better models of ZEVs are sold in the country, only ZEVs with a specified minimum range would be eligible for this regulation. In addition to the range requirement, the manufacturers would be required to follow the Phased Manufacturing Plan (PMP) to encourage the indigenized production of ZEVs in India.[162] The range would serve solely as an eligibility criterion and would not be included in calculating the ZEV requirement compliance of the manufacturer.

- **ZEV Credit Calculation**: The ZEV regulation could be piloted as a voluntary program for the first two years and later if required, it could be modified based on the performance and feedback from the automobile industry. The ACC program in California and Dual Credit Policy in China set the annual percentage of vehicles sold to be ZEVs or NEVs and then calculated the credits based on actual sales of ZEVs/NEVs. The annual ZEV requirements in India could be modelled by averaging

> The formula to calculate the ZEV requirement is as given below:
>
> ***Annual requirement for no. of ZEVs to be sold = Annual ZEV % requirement x Sales Volume (In Number)***
>
> ***ZEV credits = Actual no. of ZEVs sold by the OEM - Annual Requirement for no. of ZEVs to be sold***
>
> ***Here, one credit = 1 ZEV sold over and above the annual requirement***
>
> ***For PHEVs, the value of the credit will be less than 1 and it will depend on the all-electric drive range of the PHEV.***

the manufacturer's sales volume of three consecutive financial years prior to the start start of lead time. These annual ZEV requirements would be tailored for each vehicle category separately based on the market and technology maturity.

The annual requirement for ZEVs would be the percentage of total vehicle sales by the particular OEM required to be ZEVs across India. This requirement will be fixed for each year according to the vehicle segment and the category of the manufacturer. The ZEV credits will be calculated as a difference between the ZEV requirement and the actual number of vehicles sold by the manufacturer. If the difference is positive, then each ZEV sold over and above the requirement will earn one credit for the manufacturer. If the difference is negative, then each ZEV falling short of the requirement will be considered as a deficit. The small and medium manufacturers could be allowed flexibility in meeting the ZEV requirements as compared to the large manufacturers.

The production volume for the eligible manufacturer could be fixed based on the three-year average of the total vehicle sales of the respective manufacturer in the relevant vehicle segment. To ensure a smooth ZEV transition, manufacturers in certain categories like the e-4W may be allowed to satisfy a portion of their ZEV requirement through alternate vehicle technologies such as PHEVs or strong hybrid vehicles. Additionally, the ACC program, the validity of the credits could be for a maximum of three years to ensure consistency in the compliance of regulations and to encourage manufacturers to increase ZEV sales year-on-year.

- **Trading of ZEV Credits**: ZEV regulations across US, China and UK, allow the manufacturers to bank credits and trade them. Trading and banking of ZEV credits will provide flexibility to the manufacturers in effectively complying with the regulations. The manufacturers could be allowed to trade and bank credits until three years after the origin year of the credit.

While the price of the credits could be decided by market forces, the trading of credits could be approved by the nodal agency. The buyer and seller could submit their willingness to trade credits to the nodal agency. The nodal agency would then check the availability of credits with the seller and if sufficient credits are available then the intended credits are transferred to the buyer. Eventually, a cap could be imposed on the maximum percentage of annual ZEV requirement that could be satisfied through traded credits.

- **Mechanism to Compensate for Deficit:** In the event of any manufacturer failing to meet the ZEV requirement for a reporting period, flexibility could be given to compensate for the deficit within a certain period of time. the nodal agency could allow a

maximum time period of three years after the reporting period for the manufacturer to compensate for the deficit in meeting the ZEV requirement. The deficit could be made up in any of the following ways:

i. Carry forward valid credits from the previous reporting period

ii. Purchase credits from other manufacturers

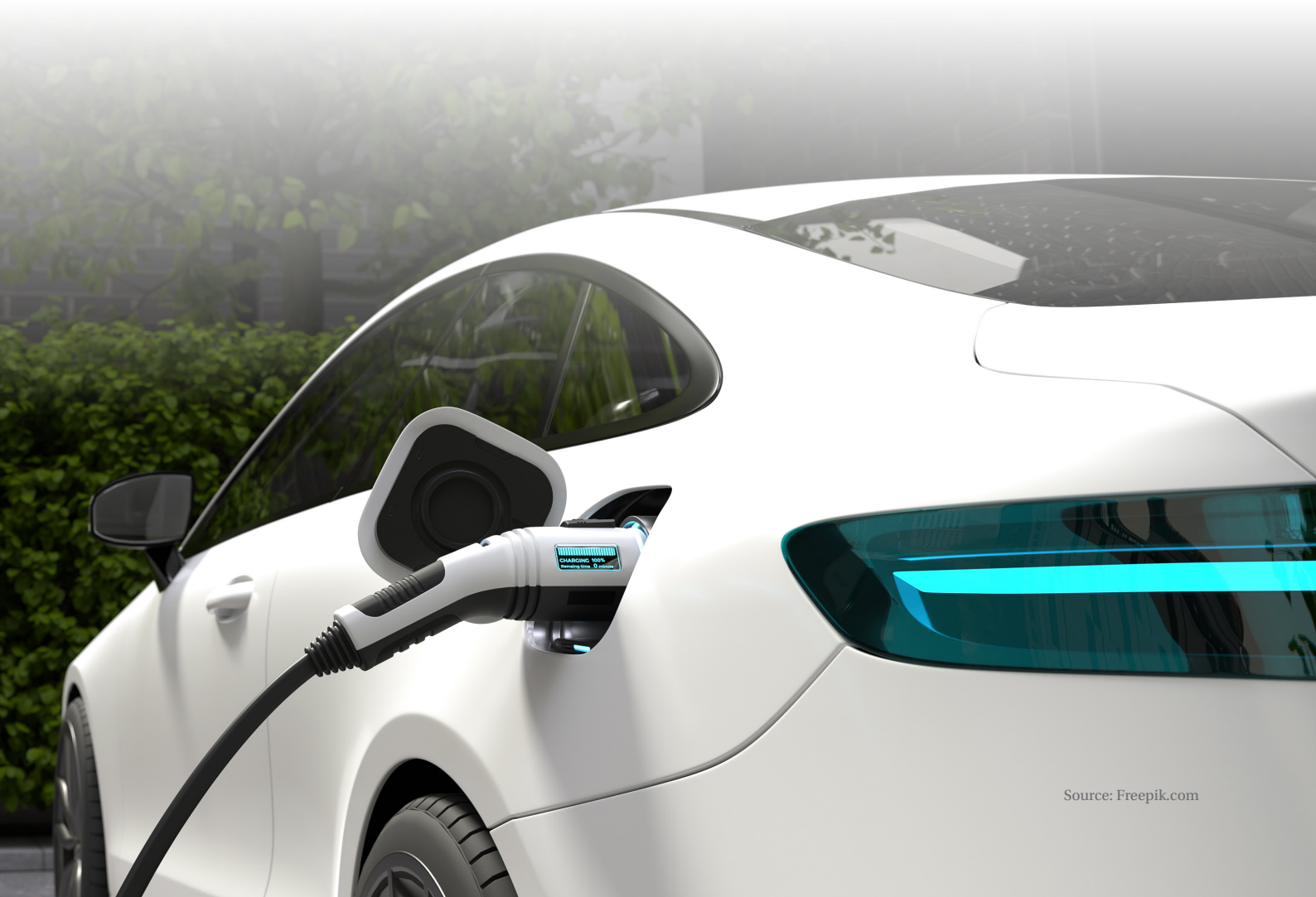
iii. Earn extra ZEV credits from over-compliance in succeeding three years

If the manufacturers fail to meet the ZEV requirements in a particular reporting period, even after the stipulated three year period, they may be subjected to suitable penalty. The penalty could be designed to exceed the cost of compliance for the manufacturers to meet the ZEV requirements.

- **Reporting Requirements:** Like the CAFE norms, a twelve-month period starting from 1 April to 31 March of the following year could be considered as a reporting period. The eligible manufacturers must submit their ZEV requirement calculations to the nodal agency. The nodal agency will maintain separate ZEV account for each manufacturer and verify the vehicle sales information from the data compiled by transport department. If the manufacturer has a deficit of ZEV credits, the nodal agency will notify the manufacturer. Within the stipulated time, the manufacturer will submit the approach for compensating for the deficit. After approval from the nodal agency, the final status of compliance for the reporting period will be sent to the manufacturers. The annual compliance report could be published on a dedicated public portal.

- **Public Dashboard on ZEV Requirements**: A public portal could be developed documenting both the yearly ZEV requirement for each manufacturer, along with their performance. From a transparency perspective, CARB has developed an Annual ZEV Credits Disclosure Dashboard which provides all the details of the ZEV requirements, credit transfers, balances and the overall trend of ZEV sales in California.[163]

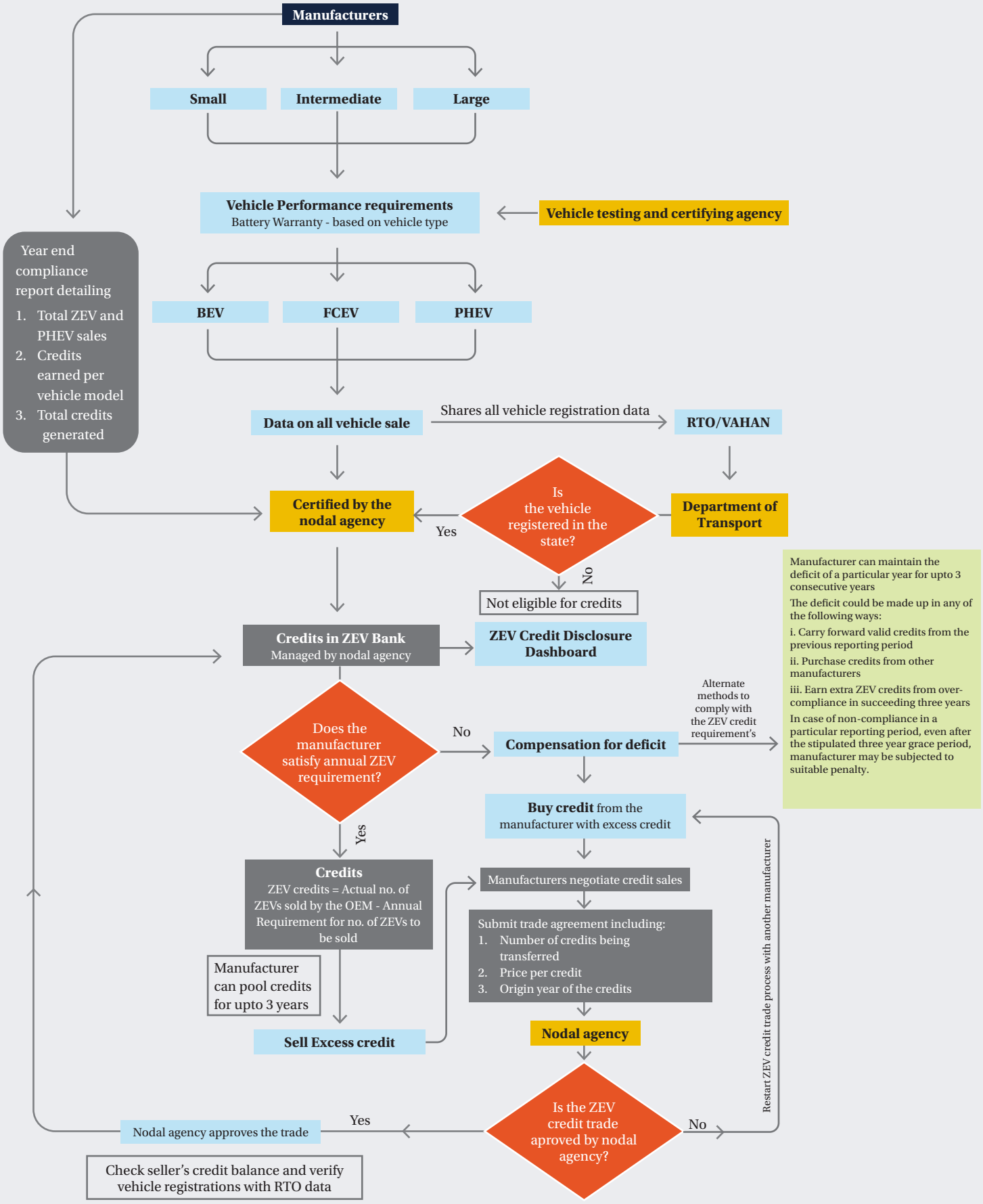
In the dashboard for India, the credits earned, traded and ending balances for each manufacturer could be published after the end of the reporting period. This would help in providing transparency and ensuring accountability. Similar to the Annual Fuel Consumption Compliance Report published by BEE for CAFE, the performance of manufacturers under the ZEV program could be published by the nodal agency.



Source: Freepik.com

The flow chart for implementation of ZEV regulation in India is given in the figure below.

Figure 17: Flow Chart for Implementation of ZEV Regulation in India



Source: NRDC Analysis

The multi-state task force in the US, successfully brought together 16 states The ZEV mandate in the US, began at a sub-national level with California as the pioneering state to implement it. Later, with the proactive approach shown by the states, the multi-state task force in the US, successfully brought together 16 states to collectively implement ZEV programs that resulted in achieving the combined target of 3.3 million ZEV sales by 2025.[164] Similarly in India, at a sub-national level, states leading ZEV sales in the country could collaborate with each other to form a ZEV coalition to fast track deployment of ZEVs. This would enable the states to take critical step forward to provide strategic roadmap for decarbonisation of road transport sector in their pursuit of achieving net-zero targets.

India imported nearly 87% of its oil demand in FY 2022-23, resulting in an import bill of USD 158.4 billion. The transport sector alone consumed 40% of the imported oil.

2.5 Benefits of Transitioning to ZEVs in India

The ZEV regulation could pave the way for increasing ZEV sales and manufacturing in India without the burden of providing demand incentives. Definitive ZEV regulations could provide policy certainty and direction for the automobile industry, complementing the other existing supply-side regulations in the country. Additional benefits of suitable supply-side regulations are listed below.

2.5.1 Reduction in Oil Imports

India has set a vision for achieving energy independence by 2047 as part of the Atmanirbhar Bharat Abhiyaan (Self-reliant India campaign), alongside the national goal of reaching net-zero emissions by 2070. It is estimated that to realize these objectives, 100% electrification of road transport by 2043 is essential, highlighting the pivotal role the transportation sector will play in achieving India's energy independence and net-zero emissions goals.[165]

To date, India is heavily dependent on oil imports. It imported nearly 87% of its oil demand in FY 2022-23, resulting in an import bill of USD 158.4 billion. The transport sector alone consumed 40% of the imported oil.[166] In FY 2023-24, the oil import bill decreased to USD 132.4 billion, primarily due to a drop in international oil prices. However, even that year, the net fuel imports increased.[167]

Research shows that India could significantly reduce fuel imports and the associated costs by electrifying its transport sector. If India achieves 100% electrification of road transport by 2043, India is projected to cut crude oil imports by nearly 91%, resulting in cumulative savings of USD 1.92 billion. Additionally, this shift is estimated to reduce carbon emissions by 14 gigatons between 2024 and 2047, an 87% decrease compared to the business-as-usual scenario over the same time period.[18]

One study estimated that by 2030, a 67% electrification of road transport could prevent 13,300 premature deaths annually; and by 2040, 95% electrification could avoid 16,700 premature deaths.

2.5.2 Positive impact on Environment and Health

The transportation sector is increasingly contributing to air pollution in Indian cities, which results in poor air quality, increasing respiratory diseases and the associated expenditure. Air pollution negatively impacts human health, and the country's high concentrations of hazardous pollutants such as fine particulate matter (PM2.5), nitrogen oxides (NOx), and sulphur dioxide (SO_2) contribute to premature deaths and other diseases.[19] These health impacts are disproportionately concentrated in the developing world, primarily due to high population densities, rising consumption patterns, and the absence of strict regulations governing the emissions of air pollutants like SO_2, NOx, and PM2.5. [168]

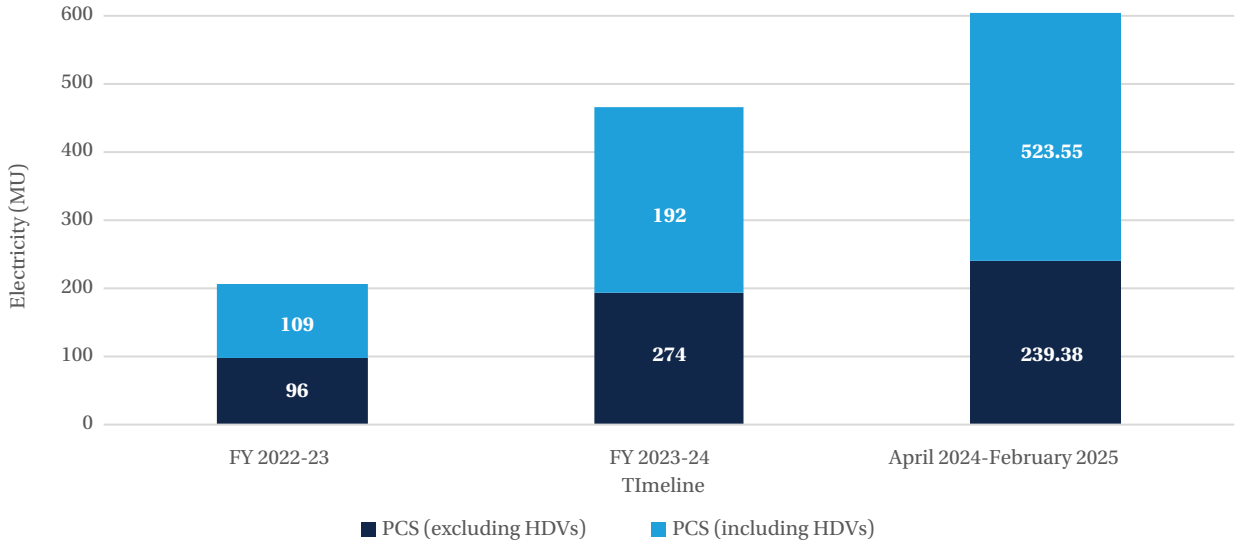
It has been estimated that in India, ambient air pollution accounts for 8,70,000 deaths per year, including 43,000 from road transportation.[160] In 2019, the economic losses due to premature deaths and morbidity attributed to air pollution, accounted for USD 36.8 billion, approximately 1.36% of India's gross domestic product.[169]

ZEVs produce significantly lower direct emissions of air pollutants compared to ICE vehicles. However, when electricity used to charge ZEVs is generated from coal-based power plants, it can lead to increased emissions of carbon dioxide (CO_2), PM, NOx, sulfur dioxide (SO_2), and other air pollutants at the generation stage. Despite this, large-scale vehicle electrification can significantly improve air quality and health outcomes in India. One study estimated that by 2030, a 67% electrification of road transport could prevent 13,300 premature deaths annually; and by 2040, 95% electrification could avoid 16,700 premature deaths. These figures assume no new policies are implemented to decarbonize the power sector during this period (that is, most electricity continues to be produced by coal).

2.5.3 Opportunity for Increase in Renewable Energy Integration

The ZEV sales in the country resulted in electricity consumption of 0.466 TWh for ZEV charging at public charging stations (PCS) in FY 2023-24. Presently, owing to the low utilization factor of PCS and predominance of domestic charging for ZEVs, there is less electricity demand for ZEV charging in the country. However, the electricity consumption for ZEV charging more than doubled from FY 2022-23 to FY 2023-24, as shown in the figure below.[170]

Figure 18: Electricity consumption from ZEV Charging in India



Source: Central Electricity Authority CEA, 2025

Recent research indicates that India will need to install more than 400,000 chargers annually, totaling 1.32 million chargers by 2030, to maintain the current annual growth rate of 40% for ZEV sales that will help it meet its clean transportation goals.[171] Depending on the vehicle categories and the power capacity of chargers used, the energy demand from ZEV charging could be assessed. According to IEA's estimates, the electricity consumption from ZEV charging relative to the final electricity consumption in the country was 0.2% in 2023 and it could vary between 6% and 8.7% in 2035 under different scenarios.[172] With increase in energy demand from ZEV charging, there is a growing need to source electricity from renewable energy sources.

Renewable energy-based ZEV charging is gaining traction and charge point operators in the country are sourcing renewable energy through different ways such as captive installation of solar panels over charging stations and by participating in green open access to purchase renewable power. By offering special time-of-day tariff for ZEV charging during solar hours, the consumption of renewable energy during the daytime for ZEV charging can be prioritized. However, battery energy storage system (BESS) will play a significant role in storing the solar energy during the day and utilizing it at night for ZEV charging when the cost of energy from the conventional grid is higher due to peak demand. ZEVs can provide flexibility in grid to integrate more renewable energy, thereby achieving the goal to generate 500 GW of power from non-fossil sources by 2030.[173] At state-level, incentives such as subsidy for solar powered charging stations, special ZEV tariffs, ratification of open access regulations for ZEV charging, have been instrumental in promoting renewable energy integration into the grid.

2.5.4 ZEV Policies as Job Catalyst: Unlocking Employment Opportunities in ZEV Manufacturing

With the rising demand across the entire ZEV value chain, including manufacturing, servicing, repair, maintenance, and recycling, there is a broad scope for jobs in manufacturing and assembly, after-sales services, charging infrastructure installation and operations, engineering design/re-design and research and development. India's ZEV market is set for rapid expansion, and it is estimated that ZEVs could make up over 40% of the automotive market by 2030, generating more than USD 100 billion in revenue.[174] This impressive growth is fuelled by government initiatives, rising consumer awareness, and advancements in ZEV technology. As the market grows, there is a substantial demand for a skilled workforce to fill various roles within the industry.

While there will be significant benefits from transitioning to ZEVs, the abovementioned benefits are important for policymakers to look at the ZEV regulation from the socio-economic and equity perspective. With the implementation of innovative supply-side regulations, policymakers could priorities ZEV transition without the burden on the state treasury from demand incentives.

Conclusion

Presently, India is at a pivotal juncture in its clean mobility transition. With 27 states and Union Territories having announced ZEV policies, many of which include ambitious ZEV penetration goals, there is a momentum building across the nation to decarbonize transport. Most of the proposed goals are aspirational rather than binding, and there is considerable variation in how these policies are operationalized on the ground. This fragmentation has led to a disconnect between ZEV ambitions and actual market outcomes.

To bridge this gap, this report makes the case for supply-side regulatory mechanisms to effectively complement demand-side incentives. Drawing on international best practices, this report explores how sales-based credit mechanisms can provide stronger market signals and accelerate the transition to ZEVs. These mechanisms not only incentivize manufacturers to scale up electric vehicle offerings but also foster healthy competition and long-term investment in ZEV ecosystems. By tailoring ZEV credit requirements to different vehicle classes based on market readiness, the approach outlined in this report presents a pragmatic yet ambitious pathway for India to harmonize policy intent with on-the-ground outcomes.

The tailored approach to to implement the proposed ZEV regulation is simple, and it could be customized and adopted at state-level. As a follow up to this report, we have developed a factsheets for Telangana and Uttar Pradesh which provide insights on the respective state's automobile industry, vehicle ownership patterns and customized approach for ZEV regulation implementation. As the way forward, a demonstration pilot could be implemented in select states to study the response from the automobile industry.

Through enhanced supply-side regulations, ZEV adoption in India will accelerate due to increase in availability of affordable ZEVs and increased investment in developing robust charging infrastructure. The supply-side regulations could complement National-level initiatives such as Automotive Mission Plan 2026, scrappage policy, and production-linked incentive scheme and enable India to extend its leadership in the automobile Industry and emerge as a powerhouse for emerging clean technologies in the transport sector.

Source: Freepik.com

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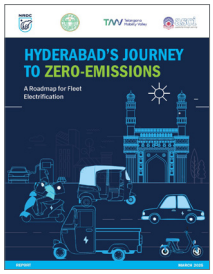
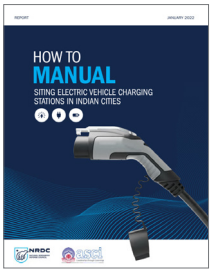
Highlighted Reports

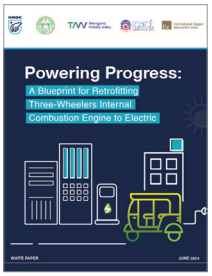


Hyderabad's Journey to Zero-Emissions



How to Manual Siting Electric Vehicle Charging Stations in India

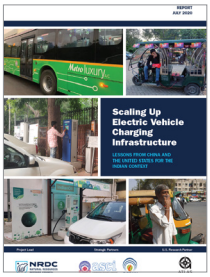
Plugging into a Clean Energy Future: Effective Deployment of Telangana's Electric Vehicle Policy



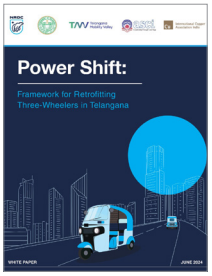
Powering Progress: A Blueprint for Retrofitting Three-Wheelers Internal Combustion Engine to Electric

Energizing Freight: Policy Toolkit for Medium and Heavy-Duty Truck Electrification in India

Location Is Everything: Approaches to Siting Electric Vehicle Charging Infrastructure for the Indian Context - Issue Brief



Scaling up Electric Vehicle Charging Infrastructure - Report



Power Shift: Framework for Retrofitting Three-Wheelers in Telangana