ENERGIZING FREIGHT:
Policy Toolkit for Medium and Heavy-Duty Truck Electrification in India

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Authors and Researchers

NRDC: Nitish Arora, Charu Lata, Charlotte Steiner

UC Berkley: Prateek Suri

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Front cover image source: Freepik

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Foreword

DR. HANIF QUERSHI
Joint Secretary
Ministry of Heavy Industries
Government of India

In the wake of India's rapid economic growth and an urgent need to address environmental challenges, the electrification of heavy-duty freight transportation in India stands as a beacon of progress and innovation.

The freight transportation landscape in India is at a critical juncture, characterized by staggering volumes and a trajectory of unprecedented growth. The statistics speak volumes: the nation currently moves a colossal 4.6 billion tons of freight annually, generating a transport demand of 2.2 trillion tonne-kilometres – or over 2000 round trips to Mars. Within this formidable landscape, the trucking sector stands as a dominant force, single-handedly accounting for 70% of this mammoth movement of goods. These figures are not mere statistics but a reflection of India's dynamic economic growth, urbanization, and burgeoning consumer demand. They signify a nation on the move, one that is propelled by the exchange of goods and services. However, while this growth is undoubtedly emblematic of progress, it also poses considerable challenges, most notably in the realms of sustainability and environmental stewardship.

The road ahead is even steeper. From 4 million trucks in 2022, this number is anticipated to surge to approximately 17 million by 2050. This dramatic rise poses both challenges and opportunities. On one hand, it presents us with the daunting challenge of mitigating the environmental impact and addressing the energy demands of this expanding fleet. On the other, it offers the potential for groundbreaking change. With lower operating costs, decreased dependence on fossil fuels, and increased operational efficiency, electrification can boost the competitiveness of India's freight sector on a global scale.

This report delves deeper into the intricacies of electrifying heavy-duty freight in India and globally, exploring the latest technologies, policy initiatives, and stakeholder perspectives. By providing a supportive regulatory framework, financial incentives, and infrastructure development, the government can catalyse the transition towards sustainable transportation. This is where Government of India's initiative, e-FAST India platform, spearheaded by Niti Aayog, aims to facilitate collaboration between stakeholders across the value chain including Original Equipment Manufacturers, Logistic Service Providers, financers, producers, and Charge Point Operators - to shape strategies and actions that support freight electrification at scale. As a testament to this, the G20 and 14th Clean Energy Ministerial event in Goa earlier this year brought together prominent manufacturing companies and logistics service providers to jointly express an ambitious demand for 7750 Zero Emission Trucks (ZET) by 2030. The Ministry of Heavy Industries is committed to put an enabling policy framework to support the transition to zero emission trucks.

I would like to commend the authors of this report for their diligence and expertise in compiling this valuable resource. The research, analysis, and presentation of best practices in this report would serve as a guiding light for policymakers, industry leaders, researchers, and all stakeholders involved in this transformative journey. Together, we can pave the way for a sustainable, cleaner, and more prosperous future for India, where heavy-duty freight transportation is powered by the limitless potential of clean power.

India currently moves 4.6 billion tons of freight annually, generating 2.2 trillion ton kilometers of transport demand

The trucking sector alone moves

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The number of trucks on the road is expected to more than quadruple by 2050— from 4 million in 2022 to roughly

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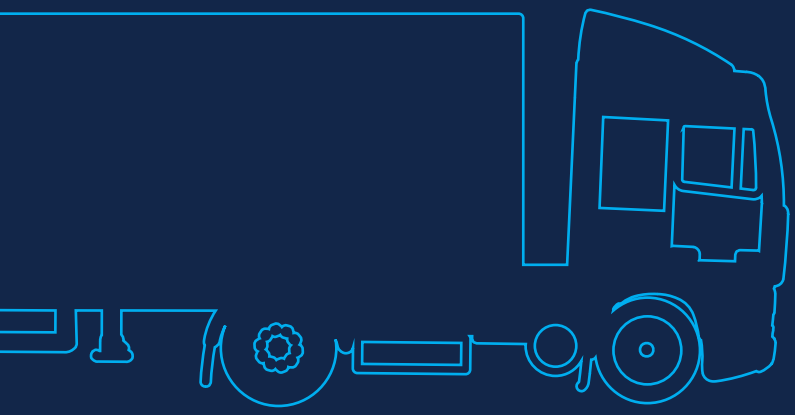

Introduction

Freight transport is central to India's economy: the transport sector's large, diverse network of trucks, cars, planes and ships plays the pivotal role of ensuring smooth delivery of goods and services for India's more than 1.4 billion people. India currently moves 4.6 billion tons of freight annually, generating transport demand of a 2.2 trillion ton-kilometres. The trucking sector alone moves 70% of the country's freight and it's only expected to grow.[1] The number of trucks on the road is expected to more than quadruple by 2050— from 4 million in 2022 to roughly 17 million.[2] Given the sector's growth and its centrality to the Indian economy, freight transport has the potential to play a pivotal role towards actualizing India's goals on energy security, public health, and climate change.

Road freight accounts for more than 25% of India's annual oil import expenditures.[3] At present, oil products, primarily diesel and gasoline, supply 95% of the total energy in the transport sector.[4] Over 82% of India's crude oil is currently sourced from abroad, and those imports are expected to more than double by 2050.[5] India's oil import bill currently stands at USD $119.2 billion—nearly double from the previous fiscal year.[6]

Electrifying road transport has the potential to save costs and reduce this dependence on foreign oil, and thus have significant impacts on energy security. Adopting zero emission trucks (ZETs) — including battery-electric trucks and fuel-cell-electric trucks — can avoid 838 billion liters of diesel consumption by 2050 or more than USD $1.3 trillion in oil expenditures.[7]

Electrifying India's transportation sector also has the potential to help lower emissions of local air pollutants, thus improving the local air quality. Over 84% of the Indian population is exposed to high concentrations of ambient air pollution, mainly from particulate matter (PM2.5).[8] India's road transport sector emitted 2.6 Mt of nitrogen oxides (NO^x) in 2021, about one-third of India's total NOX emissions, with trucks and buses, jointly accounting for about 70% of all the NOX and PM2.5 emissions from road transport.[9] Particulate matter and NO^x pollution

Source: Unsplash

associated with trucking could be reduced by nearly 40 percent by 2050 with broadscale zero emission truck adoption.[10]

The transport sector currently accounts for nearly 13.5% of the country's energy-related emissions.[11] Transport is also the fastest-growing energy end-use sector in India: with growing demand for road transport, energy consumption and CO_2 emissions from road transport in India are predicted to be three and a half to five times higher in 2050 than in 2020, based on business as usual scenarios.[12] More than 92% of India's transportation CO_2 emissions are attributable to road transportation, and 45% of such emissions come from trucks.[13] Trucks are also the fastest-growing freight transport energy use segment—the energy use has doubled since 2010 and could contribute 40%–60% of road transport CO_2 emissions by 2050. [14] This means the transportation sector has the opportunity for large scale impact: with trucks specifically, replacing diesel trucks with zero emission trucks in India could avoid up to 3.8 cumulative gigatons of carbon emissions by 2050.[15] For context, that's comparable to India's entire economy-wide annual GHG emissions today. The timing of the road freight electrification is crucial, especially as road freight demand in India is set to become the second largest in the world in the coming decade.[16]

Source: Freepik

India has made significant progress over the past few years to advance electric mobility in the country. With the launch of the FAME II program in April 2019, INR 10,000 crores (USD $1.2 billion) was earmarked to provide upfront incentives to purchase electric vehicles (EVs, including public and private two-wheelers, public three-wheelers, electric taxis and e-buses) and set up charging stations.[17] In addition, the government introduced other incentives including a reduced Goods and Services Tax (GST) on electric vehicles and chargers, Performance Linked Incentive (PLI) schemes to develop indigenous manufacturing, state-level electric mobility policies that provide an array of demand and supply side incentives, and Bharat Stage VI vehicle standards for Internal Combustion Engine (ICE) vehicles.[18]

While India has proposed strategies to decarbonize ICE passenger vehicles such as two-wheelers, three-wheelers, four-wheelers, and buses, the country remains in the early stages of extending zero-emission vehicle (ZEV) policies and programs for **Medium- and Heavy-Duty vehicles (MDVs and HDVs)*** serving road transport freights.[19] To help support development and effective implementation of truck decarbonizations programs and policies in India, this report develops an inventory of tools to accelerate and regulate the electrification of medium and heavy-duty freight. This report examines government policies and programs in other jurisdictions, examines their applicability in the Indian context, and provides recommendations for policymakers based on stakeholder discussions and best practices.

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Replacing diesel trucks with zero emission trucks in India could avoid up to 3.8 cumulative gigatons of carbon emissions by 2050

**** MDVs and HDVs are vehicles**, including passenger buses and goods vehicles, with gross vehicle weight (GVW) greater than or equal to 3.5T. In this report, "zero-emission (ZE) MDVs and HDVs" are MDVs and HDVs equipped with battery-electric technologies with no emissions of GHGs and air pollutants. ZE MDVs and HDVs include both buses and trucks, but this report focuses specifically on policies and programs related to the electrification of medium- and heavy-duty trucks.*

International Freight Electrification Background

Source: Freepik

In 2022, almost 60,000 electric medium and heavy duty trucks were sold worldwide, equivalent to 1.2% of truck sales globally.[20] China, the United States, and Europe are leading EV sales globally.[21] An estimated 52,000 of those trucks were sold in China—an 85% share of global sales, but only 4% of China's total truck sales.[22] While zero emission (ZE) truck markets worldwide remain in the early stages, this is set to change due to ambitious policies across many leading markets. For instance, 27 countries across four continents and over 70 subnational governments (including Indian states of Goa and Telangana) and private sector innovators became signatories/endorsers to the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles in 2021 and committed to a goal of 100% ZE truck and bus sales by 2040, with an interim goal of 30% new sales by 2030.[23] Already, truck manufacturers' confidence in supplying larger zero-emission models increased—of the 220 models that became available in 2022, more than half were either medium-duty tor heavy-duty trucks.[24] Zero-emission vehicle model availability continues to expand with more than 840 current and announced medium- and heavy-duty vehicle models available as of 2023.[25]

60,000 electric medium and heavy duty trucks were sold worldwide in 2022 equivalent to only 1.2% global truck sales

China, the United States, and Europe are leading in electric truck sales globally

The momentum to electrify trucks is supported by the reduced total cost of ownership of a ZE truck. A recent study by researchers at Lawrence Berkeley National Laboratory concluded that the long-term economics of battery-electric vehicles look more favorable compared to diesel vehicles. According to the research, the Total Cost of Ownership (TCO) of a 12-ton electric truck with a 222-kWh battery pack and a 300km range is 18% lower per kilometer relative to a diesel truck.[26] The TCO calculation included capital cost, fuel and maintenance cost, battery replacement every 2000 cycles. The low TCO of battery-electric trucks is driven by the significant decline in battery prices over the last decade and the long-term savings provided by cheaper fuel and low maintenance.[27] For example, a 12-ton electric truck with a 222-kWh battery pack and 300 km range could deliver a 18% lower TCO per kilometer as compared with a diesel truck (given a battery pack price of USD $135 per kWh). The payback period for recouping the electric truck's higher upfront costs would be 3.1 years, while the undiscounted savings over a 15-year vehicle life amount to INR 7,200,000 (USD $86,528).[28]

Focused policy-led incentives can help kickstart the truck electrification sector in India. Cross jurisdictional learnings adapted for Indian use and operating conditions could be useful as India moves forward with its development of policies and programs for truck electrification. The next section examines an array of policy options for medium- and heavy-duty truck electrification that have been deployed in other major economies around the world.

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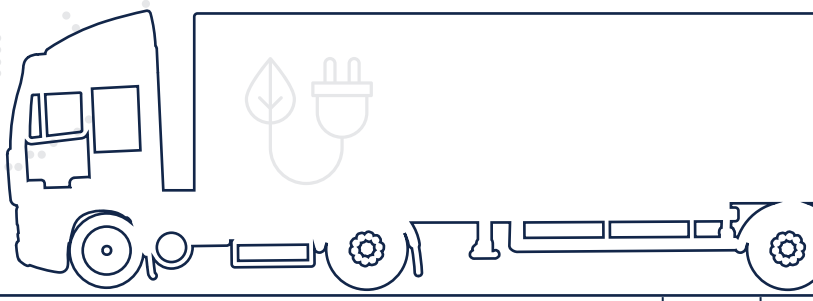
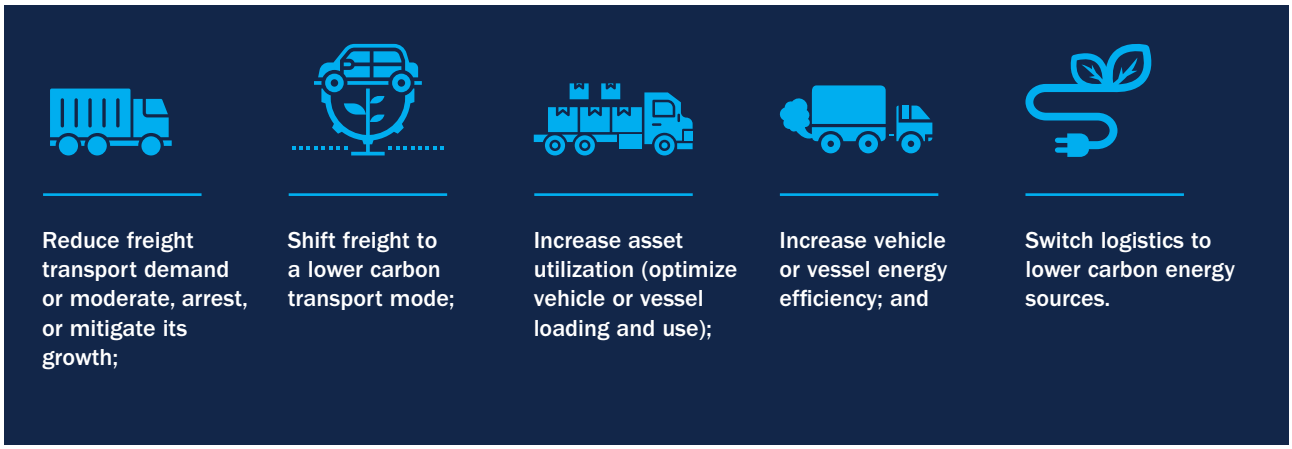


International Examples of Trucking Sector Electrification Policies

Decarbonization measures in the transport sector tend to follow the Avoid–Shift–Improve (ASI) approach.[29] ASI means i) avoiding unnecessary travel, ii) shifting traffic onto lower carbon modes, and iii) improving the carbon efficiency of personal and freight movement.[30] For freight transport specifically, this has been further bifurcated into a five-lever framework:[31]



These five levers form a balanced multi-pronged approach to reduce GHG emissions from freight transport. This report focuses on the last two levers: switching logistics to more efficient technologies such as electrification and switching to lower carbon energy sources for fuel. These levers have been the least activated thus far for MDVs and HDVs in India due to the limited availability of EV models and limited policy support, but these levers have significant potential to drastically reduce carbon emissions.

Multiple interventions could be deployed to reduce carbon emissions, including ZE commercial vehicles (batteries, hydrogen fuel cells) and highway electrification (shifting highways to supply electric power to vehicles driving on them). Some bio-based fuels (biodiesel, biomethane, and hydro-treated oils, etc.) also have potential, depending on the feedstocks and the direct and indirect land use associated with their production. This report, however, focuses specifically on policy options to promote the electrification of MDVs and HDVs. With decreasing battery costs and increased cost competitiveness, freight electrification is one of the most effective and efficient option for the complete decarbonization of long-haul trucking in India.

In this section, we highlight various policy options being adopted across different countries to drive the electrification of ZE MDVs and HDVs. These policies can be broadly grouped into six categories:

- target setting and regulatory requirements (political commitments backed by legally binding sales or purchase requirements);
- GHG/CO_2 standards (to accelerate the removal of highly polluting vehicles from the roads);
- purchase incentives (to reduce cost barriers for adopting ZE MDVs and HDVs);
- in-use and end-of-life fleet incentives (such as toll discounts and lower fuel prices to reduce vehicle operations costs;
- daytime access to city roads under certain conditions and scrappage incentives); and
- charging infrastructure (subsidies for capital investment in developing dedicated MHDV charging).[32]

a. United States

TARGET SETTING & REGULATORY REQUIREMENTS

In 2022, 3100 medium- and heavy-duty trucks were sold in the US. The United States is the second-largest truck market after China and has recently committed to 30% ZE truck sales nationwide in 2030 and 100% by 2040.[33] This commitment was preceded by a Memorandum of Understanding among 18 U.S. states, committing to the same interim target of at least 30% ZE MHDV sales by 2030.[34] Currently, California is the leading U.S. state with the most aggressive policies toward vehicle electrification.[35]

California has adopted binding annual requirements for an increasing percentage of all MDVs and HDVs sold in their states to be ZE, starting in the 2024 model year.[36] To date, six other states—Maryland, Massachusetts, New Jersey, New York, Oregon and Washington—have adopted this rule.[37] All these regulations are modeled on California Advanced Clean Trucks (ACT) regulation, which was adopted in 2020 was the world's first ZE commercial truck sales requirement.[38]

VEHICLE EMISSION STANDARDS AND FUEL EFFICIENCY STANDARDS

Vehicle emission and fuel efficiency standards are both policy tools that can lead to increased manufacturing and sales of ZE vehicles. These standards compel manufacturers to achieve performance standards either by increasing the fleet-averaged efficiency of the vehicles produced and sold in markets or through emission limits to greenhouse gases or health-harming pollutants such as nitrogen oxides, particulate matter, hydrocarbons, etc. If these standards are sufficiently strict, then manufacturers need to integrate ZE vehicle technologies into their fleet. Such policies have the potential to accelerate the development and deployment of ZEVs.[39]

The United States Environment Protection Agency (U.S. EPA) and National Highway Traffic Safety Administration have established GHG emissions and fuel efficiency standards, respectively, for heavy- and medium-duty vehicles under their statutory authority.[40] The regulations prescribe performance standards covering model years 2018-2027 for certain trailers and model years 2021-2027 for semi-trucks, large pickup trucks, vans, and all types and sizes of buses and work trucks.[41] After the completion of Phase I regulations, the Phase II regulations established "technology advancing standards," or standards that are based not only on currently available technologies but also on utilization of technologies now under development or not yet widely deployed.[42] This includes improvements in the engine, transmission, drivetrain, etc.[43] The regulatory impact analysis of these regulations shows that they will lead to significant cost savings and health benefits for consumers in addition to reducing CO_2 emissions.[44]

In December 2022, the US EPA adopted revised clean air standards for heavy-duty vehicles.[45] The standards are expected to result in a 48% reduction in nitrogen oxide, a 28% reduction in benzene, a 23% reduction in volatile organic compounds, and an 18% reduction in carbon monoxide emissions from heavy-duty vehicles by 2045.[46]

In April 2023, the U.S. EPA proposed the next round of GHG emission standards (Phase III) for heavy-duty trucks for model year 2027 and beyond. Phase I, with fuel economy standards were enacted for medium and heavy-duty vehicles for model years 2014-2018, was projected to have a reduction of 270 million metric tons of CO_2 emissions, and 530 million barrels of oil over the life of vehicles built for the 2014 to 2018 model years, saving vehicle owners more than USD $50 billion in fuel costs.[47] The Phase II program was projected to cut GHG emissions by 1 billion metric tons, conserve 1.8 billion barrels of oil, and lower fuel costs by about USD $170 billion over the lifetime of the vehicles sold in model years 2018-2027. The agency estimates that the proposed requirements for Phase III – to be finalized by the end of 2023 – would result in approximately 46% of new sales in model year 2032 being ZEVs.[48]

PURCHASE INCENTIVES

Purchase incentives or consumer subsidies (often in the form of tax credits and direct refunds) can be critical to stimulate the adoption of ZEVs across vehicle categories and will remain a key tool for MDVs and HDVs as well. The U.S. Inflation Reduction Act (IRA), enacted in 2022, provides tax credits of up to USD $40,000 or 30% of the vehicle cost, whichever is lower, for all-electric commercial vehicles greater than 14,000 lbs.[49] The enactment of the IRA is expected to provide a significant boost in MHDV sales.[50]

Privately funded ZET purchases and deployment varies by state.[51] In states where there are significant incentive or grant funding opportunities, ZET deployment and sales are higher—the policies help mitigate against ZETs' current incrementally higher costs (as compared with conventional gasoline or diesel trucks). In general, supportive electric truck policies and regulations attract the most ZET purchases and deployments.

Federally funded ZETs are deployed more broadly. For example, the U.S. Department of Energy (DOE) has supported the deployment of more than 400 ZETs, including in states without ZET adoption regulations or significant ZET purchase incentive or grant funding opportunities, like Texas, Florida, and Georgia.[52]

The incentives available for purchasing ZE heavy-duty trucks are even greater in states like California, which have ongoing state-level programs. In addition to California, 27 other US states have incentives providing funding for zero emission trucks.[53]

CHARGING INFRASTRUCTURE

Charging infrastructure is another key factor in stimulating the uptake of ZE MDVs and HDVs. For that reason, U.S. federal and state governments have adopted various policies to help drive the installation of charging infrastructure for MDVs and HDVs. The *Infrastructure Investment and Jobs Act 2021* invests USD $7.5 billion to deploy a nationwide network of 500,000 EV chargers by 2030.[54] Furthermore, the IRA provides tax credits of up to USD $100,000 or 30% of the cost per charger, whichever is lower, for alternative fuel vehicle refueling infrastructure for ten years through 2032.[55] In early 2023, the U.S. Department of energy announced USD $7 million in funding for projects dedicated to create regional infrastructure plans to support electric charging and hydrogen fueling for MHDTs along the U.S.'s most heavily trafficked routes.[56] Similarly, states have their own incentive programs to accelerate the deployment of charging infrastructure.

CASE STUDY

California leading the charge on truck electrification in United States

California has been making persistent efforts to cement its status as a world leader in forging an oil-free future. The state emerged as a leader in electric vehicle policy and implementation with other US states seen following in its footsteps.[57] The state has taken a lead in developing a range of programs that focus on rapid adoption of the cleanest available commercial technologies to innovative demonstration projects supporting commercialization.[58] In July 2023, the California Air Resources Board announced a Clean Truck Partnership today with the nation's leading truck manufacturers and the Truck and Engine Manufacturers Association to advance the development of zero-emission trucks which includes flexibility for manufacturers to meet emissions requirements while still reaching the state's climate and emission reduction goals.[59] This text box highlights some on the key policies and programs adopted in California to advance electrification of trucks in the state.

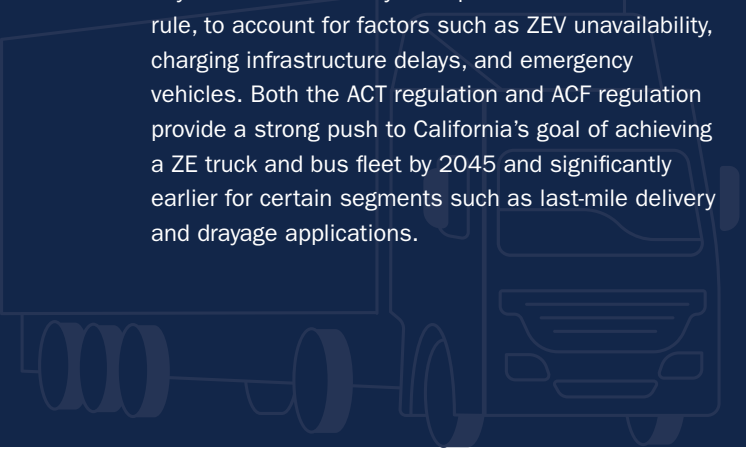
TARGET SETTING & REGULATORY REQUIREMENTS

Through the launch of California Advanced Clean Trucks (ACT) regulation in 2020, the state adopted binding annual requirements for an increasing percentage of all MDVs and HDVs sold in their states to be ZE, starting in the 2024 model year.[60] By 2035, half of all garbage trucks, tractor-trailers, cement mixers and other heavy vehicles sold in the California will be required to be fully electric—a rule that goes beyond federal requirements.[61] As of Dec 31st 2022, California had a total of 2320 total medium- and heavy-duty ZEVs (1708 Buses, 272 Trucks and 340 Delivery Vans).[62] The ACT regulation prescribes that manufacturers of MDVs and HDVs sell ZE trucks as an increasing percentage of their annual California sales starting from the 2024 model year. The sales requirements are defined separately for three vehicle groups based on gross vehicle weight rating (GVWR): Class 2b-3 trucks and vans (GVWR from 3.8 to 6.3 tons),

Class 4-8 rigid trucks (GVWR greater than 6.3 tons), and Class 7-8 tractor trucks (GVWR greater than 11.8 tons).[63]

Furthermore, the ACT regulation relies on a credit-deficit system for compliance. Manufacturers selling ICE trucks in California generate deficits based on the volume of such trucks sold. To comply with the ACT regulation, a manufacturer must offset its total deficits for a given model year and vehicle class by generating credits through sales of ZE trucks.[64] This means that deficits accrued in a certain class of vehicles can only be offset with credits from the same vehicle class, and likewise for other vehicle groups. However, the regulations allow for trading excess credits between manufacturers to encourage industry leaders while providing additional flexibility to potentially slower companies. While the ACT regulation sales requirements enter into force starting from the 2024 model year, early compliance is rewarded as credits begin to accrue until three years before the first sales requirements enter into force (and credits can be banked until 2030). A manufacturer's non-compliance with the ACT regulation is treated as a violation of the state's emission standards and penalized accordingly.

In addition, California adopted the Advanced Clean Fleets (ACF) regulation in April of 2023 to complement the ACT regulation.[65] The ACF regulation stimulates demand for ZE commercial vehicles by requiring large private and public fleet owners to purchase an increasing percentage of ZE MDVs and HDVs over time. The regulation applies to fleets performing drayage operations, those owned by government agencies, and high-priority fleets.[66] The ACF regulation would be phased in over time, with an end to sales of ICE trucks by 2036. However, fleet owners can continue to operate ICE vehicles beyond this time. Many exemptions exist within the rule, to account for factors such as ZEV unavailability, charging infrastructure delays, and emergency vehicles. Both the ACT regulation and ACF regulation provide a strong push to California's goal of achieving a ZE truck and bus fleet by 2045 and significantly earlier for certain segments such as last-mile delivery and drayage applications.



PURCHASE INCENTIVES

In addition to the tax credit support through IRA, the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), launched in 2009 and funded by California's Cap and Trade carbon program, provides point-of-sale vouchers of up to USD $375,000 per vehicle to make advanced vehicles more affordable. A pilot project under HVIP reserves USD $25 million exclusively for helping small trucking fleets and independent owner-operators access ZE trucks.[67] More than 60% of California's zero-emission trucks on the road as of January 2022 were directly funded by HVIP.[68] Similarly, California has also instituted programs, such as the Truck Loan Assistance Program, to help small-business fleet owners who don't meet tradition lending criteria secure loan financing for upgrading their fleets with newer clean trucks.[69] Implemented through the California Pollution Control Financing Authority's California Capital Access Program, the program is a loan loss reserve program, which encourages banks and other financial institutions to make loans to small businesses by potentially providing up to 100% coverage on loan defaults.[70]

CHARGING INFRASTRUCTURE

In California, the Low Carbon Fuel Standard (LCFS), the California Energy Commission's (CEC) Clean Transportation Program, and the California Public Utilities Commission's (CPUC) investments in MHDV charging infrastructure all aim for accelerated investments in developing charging infrastructure by providing tax credits under LCFS, by direct investments under CEC's program and through utilities' investment through CPUC programs. In November 2022, the California Public Utilities Commission (CPUC) adopted a five-year, statewide, USD $1 billion transportation electrification program to build a unified policy-driven funding structure for utility transportation electrification efforts through 2030. 70 percent of these funds were earmarked for charging medium-and heavy-duty vehicles. The program prioritizes investments in charging infrastructure for low-income, tribal, and underserved utility customers including distribution grid upgrades and promoting vehicle-grid integration.[71]

b. Europe

TARGET SETTING & REGULATORY REQUIREMENTS

The European Commission has set a binding target of achieving carbon neutrality by 2050.[72] The European Parliament and European Council recently reached a political agreement to ban sales of ICE cars by 2035, with an exception for Germany, which is permitted to sell and register ICE models after the 2035 deadline provided those vehicles operate only on carbon-neutral fuels.[73] While the EU has no specific target for electrification of the MHDV segment yet, many European countries have set targets to decarbonize MDVs and HDVs. For instance, Norway has a target of ensuring all new heavier vans and goods distribution vehicles used in the biggest city centers, and 50 percent of new trucks, be ZEVs by 2030.[74] The United Kingdom has a target of phasing out non-ZE Heavy Goods Vehicles (HGVs) less than or equal to 26 tons by 2035, and all new non ZE HGVs sold in the UK by 2040.[75] Austria has announced a national Mobility Master Plan, which sets targets to end the sale of conventional MDVs and HDVs under 18 tons by 2030 and by 2035 for those over 18 tons.[76] As discussed below, Europe heavily relies on the "users pay" and "polluters pay" principles to address the GHG emissions related to road transportation.[77]

EMISSION STANDARDS

In 2019, the European Union set CO_2 emission performance standards for new heavy-duty vehicles (EU CO_2 Regulations).[78] The new standards require reducing CO_2 emissions of regulated segments of medium- and heavy-duty trucks by 15% by 2025 and 30% by 2030 (on average, relative to 2019-2020 baseline levels).[79] The regulated segments correspond to rigid and tractor trucks with a GVWR exceeding 16 tons. These regulations only cover vehicles used to deliver goods, accounting for 63% of European truck sales.[80] The EU CO_2 Regulations ensure compliance by requiring a manufacturer to meet its average CO_2 emissions against the manufacturer-specific targets. Zero- and low-emission vehicles credits allow manufacturers to reduce their compliance target, which are difficult to meet, but only by up 3% or less.[81]

Various experts suggest that the 2019 EU CO_2 Regulations will not effectively reduce CO_2 emissions and will potentially hinder the EU's goal of achieving carbon neutrality by 2050, given the projected 44% increase in freight activity over the period 2020–2050, which would diminish the CO_2 reduction benefit of the standards.[82] To address these challenges, the European Commission proposed a revision of these regulations in February 2023. If the Commission's proposal is adopted by the European Parliament and European Council, it would introduce new, stronger CO_2 emission standards for heavy-duty vehicles from 2030 onwards and extend the scope of the Regulation to cover smaller trucks, city buses, long-distance buses, and trailers.[83] The proposed regulations are one of the most ambitious standards introduced in any major vehicle market for trucks and buses: the proposed standards are projected to reduce cumulative emissions from trucks and buses by 1.8 billion tons of CO_2 by 2050, amounting to a 64% reduction in annual emissions by 2050 relative to 1990.[84]

PURCHASE INCENTIVES

Nearly all EU countries offer some incentive for purchasing ZE vehicles in the passenger car segment, but only a few such incentives are currently available for MDVs and HDVs. France is providing 40% of the purchase cost of ZE HDV up to EUR 50,000; Germany is providing up to 80% of the price differential between ZE HDV and Euro VI diesel equivalent models, and the UK government is providing plug-in truck grants (PITrG) to reduce the purchase price of HGVs by 20%, with up to £25,000 of funding available for trucks heavier than 12 tons.[85] The UK's PITrG requires the applications for subsidies to be submitted by manufacturers for each eligible model, and subsidies are made available to customers at the point of purchase in the form of deductions.[86] Manufacturers or their selected dealerships submit claims monthly to receive the subsidies.

IN-USE FLEET INCENTIVES

The European Parliament has applied the "polluters pay" principle to freight movement on trans-European transport (TEN-T) network roads by adopting a directive that offers up to 75% toll discounts to ZE MDVs and HDVs, among other ZE vehicles (starting early 2024).[87] The toll discounts will be pegged to the CO_2 emission levels of the vehicle, where maximum discounts are available for vehicles with the lowest emissions. The regulations provide discounts to both electric and

hydrogen fuel cell-based vehicles. The directive allows EU member states to use their discretion to provide even larger toll discounts or even toll exemptions.[88] Given that road tolls for HDVs may cost €25,000 a year per truck annually, switching to ZEVs will lead to significant savings.[89] The directive further provides the option of imposing additional CO_2 cost charges on polluting vehicles.[90]

CHARGING INFRASTRUCTURE

The EU Parliament approved regulations on the deployment of alternative fuel infrastructure (AFIR Regulations) across the EU in March 2023.[91] These new regulations set mandatory deployment targets for electric recharging and alternative fuel (hydrogen, liquified methane) refueling infrastructure for cars, trucks, ships and planes across the EU to avoid range anxiety, i.e. fear that a vehicle will not have enough battery charge to reach its destination. The AFIR Regulation targets deployment of electric charging stations dedicated to HDVs with a minimum output of 350 kW at every 60 km along the Trans-European Transport (TEN-T) core network, and every 100 km on the larger TEN-T comprehensive network from 2025 onwards, with complete network coverage to be achieved by 2030.[92] Safe and secure parking areas for overnight recharging, as well as in urban nodes (for delivery vehicles), are also targeted locations for setting up EV charging stations.

OTHER INNOVATIONS

Germany has been experimenting with the catenary system—a system that feeds electricity to trucks as they drive, using wires strung above the roadway—to understand if it is a feasible option for road freight decarbonization.[93] Currently, a segment of German highway (six miles total) has been equipped with overhead cables for testing. The catenary system presents many advantages, including efficiency and no loss of freight load capacity due to much smaller batteries.[94] However, the costs of building such an extensive system (approx. 2.5 million euros per kilometer) may be prohibitive.[95] Similar experiments have been performed earlier, for instance, in Los Angeles in 2017.[96] The prospects seem enticing, but it remains to be seen if this technology will be cost-effective.

Source: Unplash

c. China

TARGET SETTING REGULATORY REQUIREMENTS

China has set the target of achieving economy-wide carbon neutrality by 2060.[97] MDVs and HDVs account for nearly half the total road transportation GHG emissions and over 90% of particulate matter pollution from all vehicles in China.[98] The Chinese truck market is exhibiting tremendous year-on-year growth of nearly 90%, and just in August 2022, 7,831 new energy truck units were sold.[99] New energy vehicles (NEVs), a term used specifically in China, includes battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell electric vehicles (FCEV).

China has set a target to fully electrify its public sector vehicles (comprising buses, sanitation vehicles, postal vehicles, urban logistics vehicles, and other types) by 2035, as outlined in its New Energy Vehicle Industry Development Plan (2021-2035).[100] This objective has been repeatedly emphasized through a series of policies issued by central government agencies and implemented by subnational governments. The central government has also recently initiated a nationwide pilot project to fully electrify public sector vehicles, with specific localized targets set for electrification levels and the development of charging and swapping infrastructure (stations at which drivers can exchange depleted batteries for recharged ones).[101]

The seeds of China's NEV policy were planted as far back as the 1990s. It was formally incorporated into the 10th Chinese Five-Year-Plan to promote the "Three-by-Three Research and Development Strategy," which promotes three technologies—fuel cell, hybrid, and electric—and three component technologies: powertrain control systems, driving motors, and batteries.[102] In 2010, the NEV industry was prioritized as one of China's top emerging industries of strategic importance.[103] Since 2017, the Chinese government has incentivized the sale of electric vehicles by setting targets for NEV sales, providing grants and discounted loans to support industry development, and providing direct subsidies and tax incentives/waivers to offset the upfront cost differential under the NEV mandate. The NEV mandate is also called the "Dual Credit," as businesses receive credits for both NEV sales and average fuel efficiency, and surplus NEV credits can be used to offset deficits in corporate average fuel consumption credits.[104]

PURCHASE INCENTIVES

In 2020, China released its revised subsidies policy for promoting sales of both commercial and passenger class NEVs including trucks.[105] The decade-long policy providing purchase incentives to stimulate the growth of NEVs was extended for another two years to the end of 2022. Since the 2019 iteration of this policy, China has shifted away from providing direct subsidies for hydrogen fuel cell vehicles given infrastructure constraints.[106] China has instead increased investment in research and development and application demonstrations through pilot programs.[107]

For trucks, the subsidies are determined as a function of their battery capacity and are further subject to various ceilings dependent on technology type and vehicle weight class.[108] For example, a truck weighing 12 tons or more may receive up to CNY 50,000 (USD 7,085) in subsidies.[109] The subsidy will be available to only two million NEVs per year from 2020 to 2022 (all classes combined). In addition, the policy mandates certain checks to ensure that the policy incentives are not being abused. For instance, non-private NEVs must demonstrate at least 30,000 km of accumulated mileage to qualify for the subsidies.[110] The NEV Subsidies Policy further restricts local governments from providing additional upfront purchase subsidies for NEVs greater beyond what is provided under the central policy. Instead, local governments are encouraged to provide incentives to develop charging infrastructure.[111]

The NEV Subsidies Policy was expected to be the last iteration of the policy before China phases out such subsidies altogether. However, with nearly 6 million NEV sales across China in 2022, the government extended the tax break (which on average accounts for 10 percent of the vehicle cost) on the purchase of electric vehicles until the end of 2023.[112] China has utilized subsidies to support the production and sales of electric buses and trucks since 2016: in 2016 and 2017, the vast majority China's nearly 30 billion yuan (USD 4.3 billion) in subsidies went to electric buses.[113] While China continued to support sales with subsidies, by 2021 and 2022, sales grew from 59,000 to 186,000 even as subsidies on a per-vehicle basis started declining, illustrating

that the NEV market may be competitive without government support.

CO_2 STANDARDS/FUEL ECONOMY STANDARD

China does not have any direct, enforceable regulation for curbing GHG emissions from MDVs and HDVs, although CO_2 emissions are regulated indirectly through fuel consumption standards, which were introduced back in 2012. The transportation sector the provides critically important opportunities for fostering synergy between CO_2 emission reduction and air pollution control. To achieve these objectives, the Chinese government intends to progressively advance the electrification of public sector vehicles by exploring demonstration pilots and commercial operation of electric MDHV. These approaches are clearly indicated in the *Implementation Plan for Synergistic Reduction of Pollution and Carbon Emissions* launched by Ministry of Ecology and Environment in 2022.[114]

CHARGING INFRASTRUCTURE

In January 2022, China issued the policy document "Implementation opinions on further improving the service guarantee capacity of electric vehicle charging infrastructure."[115] Under this policy, there are two provisions that support MHDV charging:

- Article 8 supports highway fast charging by committing to 80% coverage rate of fast charging stations on highways, national ecological civilization pilot areas (provinces specially designated to explore new practices for ecological preservation), and key areas for air pollution prevention and control—with other areas meeting at least 60% coverage by 2025;
- Article 13 supports the construction and layout of dedicated battery swap stations in areas such as mines, ports, and urban transshipments. (Currently, 55% of pure electric heavy trucks in China use battery swapping stations and 45% use stationary charging.[116])

The same policy document also includes a provision to increase financial support for installing charging infrastructure in the country.

d. Other countries

Canada and Chile, among others, have also set ZE targets for MDVs and HDVs. Canada aims to have 35% ZEV sales by 2030 and 100% ZEV sales by 2040 for a subset of vehicle types based on feasibility.[117] To achieve this, it has proposed an investment of USD $421 million for an MHDV purchase incentive program, USD $26 million for hydrogen trucking demonstration projects, and a 100% tax write-off until 2023 for businesses investing in heavy-duty ZEVs. The tax write-off will decrease after 2023. Similarly, Chile recently announced National Electromobility Strategy targets of 100% ZE MDVs and HDVs sales by 2045.[118]

Source: Unplash

Truck electrification in India

Truck fleets travel more than 100 billion kilometers every year in India, equivalent to more than 130,000 return trips to the moon. [119] For India to become net zero by 2070, electric trucks will need to be at least 79% of the total trucking industry.[120] Medium Duty Trucks (MDTs) have historically dominated the Indian trucking market, but over last few years, the demand for Heavy Duty Trucks (HDTs) has increased significantly: the market share of HDTs grew from 42% in 2014 to 63% in 2021.[121] This trend is consistent with other major economies, highlighting the fact that as countries become wealthier and have improved infrastructure and road networks, the share of loads carried by MDTs declines while HDTs loads increase.[122]

Currently, 50% of India's vehicle freight traffic movement is concentrated along seven major corridors, that travel along the six national highways connecting the country's cities and ports.[123] Below is a recent analysis by Global Drive to Zero mapping the vehicle type, load capacity required, daily driving distance & potential charging infrastructure needs across the golden quadrilateral corridors.[124] The concentration of road freight travel and economic activity along these corridors presents an opportunity to strategically prioritize and set up enabling infrastructure to scale ZET adoption. ZET demonstration pilots on these high-use routes is critical to build market momentum and stakeholders confidence in this nascent technology.

Source: Freepik

India's Electric Vehicle Policy Landscape

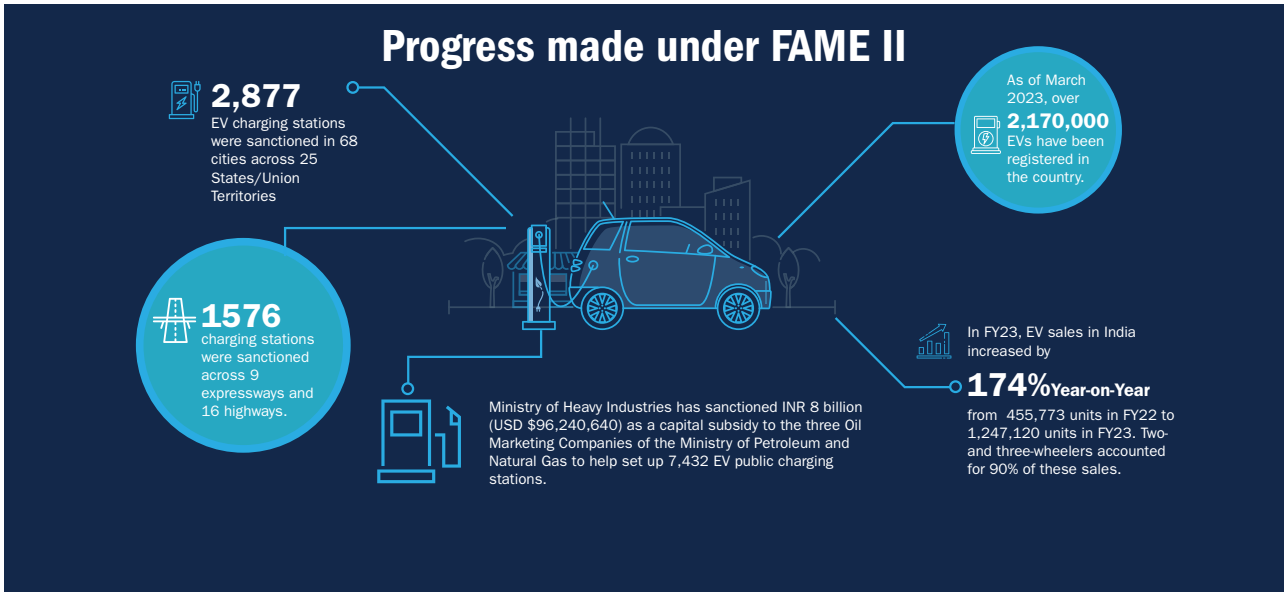
India's electric vehicle journey started in 2013, with the release of the National Electric Mobility Mission Plan 2020 which outlined India's goal of reaching 30% EV sales by 2030. This was followed by the FAME II (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) India Scheme in 2019 with a total budgetary support of INR 10,000 crores (USD $1.4 billion) for a period of five years.[125] The FAME II India scheme supported the electrification of public and shared transportation and aimed to provide demand incentives for 7090 e-Buses, 500,000 electric three-wheelers, 55,000 electric four-wheeler passenger cars and 1000,000 electric two-wheelers. The creation of charging infrastructure has also been supported under the Scheme. More than 800,000 vehicles have been supported through FAME II scheme through July 2023.[126]

The Indian government has further prioritized setting up EV charging stations across cities & highways. As part of FAME II, 2,877 EV charging stations were sanctioned in 68 cities across 25 States/Union Territories and 1576 charging stations across 9 expressways and 16 highways.[127] The Ministry of Heavy Industries has also sanctioned INR 8 billion (USD $96,240,640) as a capital subsidy to the three Oil Marketing Companies (OMCs) of the Ministry of Petroleum and Natural Gas (MoPNG) to help set up 7,432 electric vehicle public charging stations.[128]

In FY23, EV sales in India increased by 174% Year-on-Year from 455,773 units in FY22 to 1,247,120 units in FY23).[129] As of March 2023, over 2,170,000 EVs have been registered in the country.[130] 90% of these EVs are two- and three-wheelers.[131]

In addition to schemes like FAME, there has also been governmental support for the creation of a robust manufacturing ecosystem for EVs and its components. The objective is to enhance domestic value creation and create more livelihood opportunities. For instance, for vehicles to be eligible for demand incentives under the FAME-II scheme, vehicle original equipment manufacturers need to meet the localization criteria as specified under the Phased Manufacturing Program. This scheme requires half of the vehicle components to be locally sourced in India.[132] On the supply side, the Government has leveraged its Productive Linked Incentive (PLI) scheme with the objective to enhance India's manufacturing capabilities for Advanced Automotive Products (AAT).The Auto PLI scheme has thus far been successful in attracting proposed investment of INR 67,690 crore (USD $8.1 billion), exceeding the target estimate of investment INR 42,500 crore (USD $5 billion) that was set for the five years between 2022-2027. Another investment of INR 27,000 crore (USD $3.2 billion) is being envisaged under the Advanced Chemistry Cell (ACC) battery PLI scheme, which aims to create a manufacturing capacity of 50 Giga Watt Hour of ACC and 5 GWh of "Niche" ACC.[133] The Indian EV sector has already seen $3.7 billion private equity and venture capital investments in this space over the past three years, and this number looks set to increase significantly as the industry transforms.[134]

India has initiated regulations that will lay the groundwork for setting fuel-economy and emissions standards for trucks in its journey to adopt zero emission trucks. The fuel-efficiency standards for commercial HDVs regulations—developed through a combined effort of the Ministry of Road Transport and Highways (MoRTH), the Petroleum Conservation and



Research Association (PCRA, which is part of MoPNG), and the Bureau of Energy Efficiency—requires trucks to improve their fuel consumption (km/litre) in increments. The regulations were implemented in two phases.[135] In April 2023, the phase II of Bharat Stage VI standard was also implemented across India to regulate vehicular emissions of air pollutants.

India is currently considering phase III of the FAME scheme, which would extend demand incentives to newer vehicle segments including electric trucks.[136] In pursuit of decarbonizing the freight sector, newer initiatives to facilitate the deployment of electric trucks have also been launched. These initiatives are discussed in detail in the next section.

TRACKING INDIA'S PROGRESS TOWARDS ZERO EMISSION TRUCKS: LARGE-SCALE INITIATIVES

The national policy think tank, Niti Aayog, launched the E-FAST (Electric Freight Accelerator for Sustainable Transport) platform in September 2022 that convenes various stakeholders across the freight value chain.[137] The first-of-its-kind platform aims to raise awareness about freight electrification and facilitate on-ground demonstration pilots. These pilots can provide evidence-based inputs for informed policy decisions to accelerate freight electrification in India.

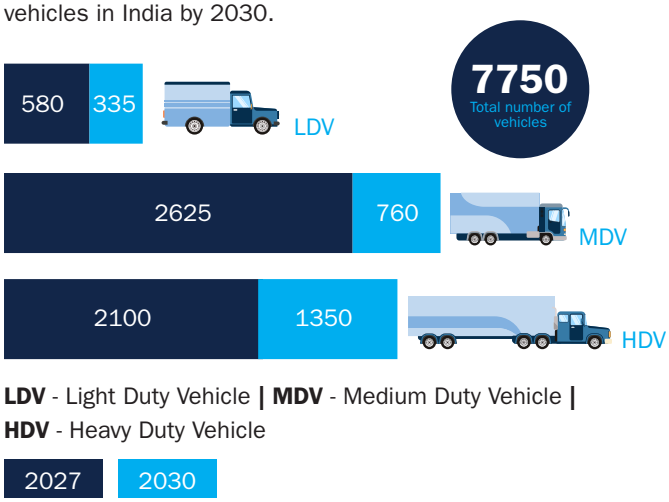
In support of accelerating transition to zero emission trucks (ZETs) in India, CALSTART, UC Davis, and The Climate Group collaboratively launched the Zero-Emission Truck High-Level Ambition Group (ZET HLAG) for India at the 14th Clean Energy Ministerial meetings in Goa. The ZET HLAG coalition brings together top Indian commercial vehicle and component manufacturers and infrastructure providers including the Volvo Group India, Daimler India Commercial Vehicles, Mahindra & Mahindra Ltd, Ashok Leyland, Tata Motors, EVage and Omega Seiki Mobility. The goal of the coalition is to collaboratively identify and work to achieve a strong mix of policies, programs, incentives, and partnerships to accelerate India's zero-emission transport sector.[138]

ZET CORRIDOR DEVELOPMENT

To facilitate large scale deployment of ZETs, India is also working on developing electric highways, or electrically augmented roads that can supply power to travelling vehicles by using overhead power lines or power lines pre-set on the roads themselves.[139] which will be powered by solar energy, to facilitate the charging of heavy-duty trucks and buses.[140] A plan for ZET demonstration pilots was announced at the 14th Clean Energy Ministerial meeting in July 2023 in Goa. ZET demonstration pilots on high-use routes can provide an opportunity to test new technologies, business models, etc. As India moves forward with implementation, prioritizing special economic zones for these demonstration pilots can help catalyze the market and lead to widescale adoption well beyond its own geography.

India's first zero-emission road freight cluster is being implemented along the west coast of Gujarat and Maharashtra.[141] Together, these two states account for a combined GDP of USD $700 billion, with ports in the states handling about 50% of India's total volume of cargo. As one of busiest cargo movement routes, the region is an ideal candidate for developing India`s first zero-emission road freight cluster. During the 14th Clean Energy Ministerial meeting in July 2023 in Goa, Indian businesses committed to deploying over 550 zero-emission trucks in the cluster in the next 18-24 months.[142] To enable effective implementation of cluster-based approach involving multiple stakeholders and sectors, commitments to support deployment of shared assets and infrastructure will also be key. These commitments can, in turn, incentivize OEMs on the supply side to invest in supply chains and help develop a robust servicing ecosystem.

India has also carried out a demand aggregation exercise for ZETs in India to illustrate to OEMs that the demand exists and to support further investment. During the 14th Clean Energy Ministerial meeting and Niti Aayog's G20 event in Goa in July 2023, prominent Indian conglomerates came together to express a demand for 7,750 ZETs by 2030.[143] These include companies from varied sectors ranging from cement, chemicals, dairy and food.[144] The below figure provides the breakdown of the overall demand signaling, or potential total demand, for light, medium and heavy-duty vehicles in India by 2030.



Source: Author's compilation from Niti Aayog, G20 event in Goa, 2023

STATE-LEVEL ACTIONS

The state of Telangana endorsed a Global Memorandum of Understanding (MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles (ZE-MHDVs) at the 2021 United Nations Climate change conference a strong support for ZE-MHDVs. The MOU aims for 30% new MDVs and HDVs being zero emissions by 2030, and 100% by 2040.[145] At the 14th Clean Energy Ministerial, Goa became the second Indian state to endorse the Global MOU on ZE-MDVs and HDVs.[146]

The state of Maharashtra established a target of making four highways fully EV ready by 2025 and has identified the need for corridor charging specifically for long-haul electric trucks as part of its Electric Vehicle Policy. [147] This is noteworthy as one of the only references to heavy-duty vehicle electrification in a state EV policies document, and an important starting point to enable ZET deployment in Maharashtra.[148]

TELANGANA'S FORWARD LOOKING APPROACH

Telangana was the first Indian state to commit to the Global Memorandum of Understanding on Zero-Emission Medium-and Heavy-Duty Vehicles at COP26. It showed the state's commitment to decarbonize its freight sector. Zero Emission Trucks (ZETs) can significantly reduce CO_2 emissions from this sector. It also reduces the disproportionate exposure to air pollution for frontline communities engaged in goods movement. This policy toolkit by NRDC India and ASCI will provide the necessary guidance and structure for setting up a regulatory framework that supports the growth of heavy-duty freight electrification in India, thus, moving the country towards achieving its environmental, economic, and energy-security goals.

Carefully designed pilot projects in closed-loop ecosystems that identify vehicles and route cycles are a great way to start an assessment, same covering metrics such as, the kind of vehicles deployed, existing vehicle movement and how these vehicles are powered. This will help develop informed and intelligent design, capital budget forecasting and predict future power needs amongst others. This can be incorporated into a broader-scale deployment of ZET's in the future. In this context NRDC India and ASCI are currently doing a techno-commercial assessment of how ZETs and electric construction machinery can be inducted in the fleet of major Coal Mining company in the state. The mines use hundreds of vehicles as well as heavy earth-moving machinery, all of which consumes a lot of fuel. Additionally, some of the payloaders that lift coal can be connected to the charging infrastructure. That is where we see a lot of potential. Such an assessment will ensure that the pilots are set up for success and will also provide a roadmap for the scale up.

JAYESH RANJAN,
Principal Secretary,
Department of Industries & Commerce (I&C) and Information Technology (IT),
Government of Telangana

FEASIBILITY ASSESSMENT OF CLOSED LOOP ECOSYSTEM TO KICKSTART ZET PILOT IN TELANGANA

GREENING THE QUARRY: DECARBONIZATION OF THE COAL MINE FLEET

NRDC and ASCI has collaborated with a major coal mining company in the state of Telangana to conduct feasibility studies regarding the electrification of heavy-duty trucks and dumpers used in the company's quarry operations.

Our preliminary assessment of one of the open-cast mining site which had a fleet of thirty-nine 60-tonne dump trucks revealed that the electrification of these dumpers can lead to an average annual reduction of approximately 10,612 tCO_2eq in tailpipe emissions. On an average, a 60-tonne dumper consumes 31 liters of diesel per hour and operates for approximately 3,310 hours per year. This implies that converting a single 60-tonne dumper to electric power would result in an average annual reduction of 270 tCO_2eq in tailpipe emissions.

Furthermore, research has revealed that particulate pollution levels are notably high in haul roads, second only to the drag line section, in open-cast mining projects where overburden and/or mined coal transportation occurs. This elevated pollution is attributed to both dust and vehicular emissions, with significant consequences for the health of mining personnel. Electrification, in conjunction with existing measures like water spraying on haul roads, offers the advantage of reducing particulate matter emissions from vehicles, thereby enhancing the well-being of frontline workers and benefiting the environment. Notably, the potential for decarbonization and its impact increases substantially when considering other heavy-duty equipment typically used in quarry sites, such as shovels, loaders, and water sprinklers.

Moreover, there is an opportunity to harness renewable energy sources, like solar ground-mounted installations or open access arrangements, for charging, enabling a genuinely clean transition in freight operations. Consequently, closed systems and sites offer a promising prospect to plan, design, finance, and execute electrification pilot projects, identifying routes to scale both environmental and social benefits.

CASE STUDY

Businesses pilot ZET and plan for scale up

Several Indian conglomerates have committed to decarbonizing heavy-duty freight in India, with several piloting ZETs on fixed route use cases. For instance, Adani Ports and Special Economic Zone (APSEZ) has started with battery-operated trailer trucks at their ports in Gujarat and Tamil Nadu. As of July 2023, the company operates a fleet of 263 trucks in Gujarat and 75 in Tamil Nadu, and has announced further plans to electrify most of its port equipment and power via renewable electricity.[149]

Earlier this year Adani Enterprises Ltd. (AEL) had also signed an MoU with Ashok Leyland, and Ballard Power of Canada to start a pilot project to develop a hydrogen fuel cell electric truck for mining logistics.[150]

Can H2-ICE retrofit solutions be a reliable & faster way to decarbonize heavy duty vehicles?

Retrofitting consists of removing certain mechanical components of a vehicle (engine, transmission, etc.) and replacing them with an electric drive train/propulsion system, or, in some cases, with a hydrogen range extender (H2 tanks). The truck would then no longer run on diesel, but on electricity and hydrogen. A recent study by the French Agency for Ecological Transition (Ademe) found that the retrofit for a 16 to 19 ton truck reduces CO_2 emissions by 87% compared to a diesel vehicle and by 37% compared to a new electric truck (on account of reduced use of raw materials).[151]

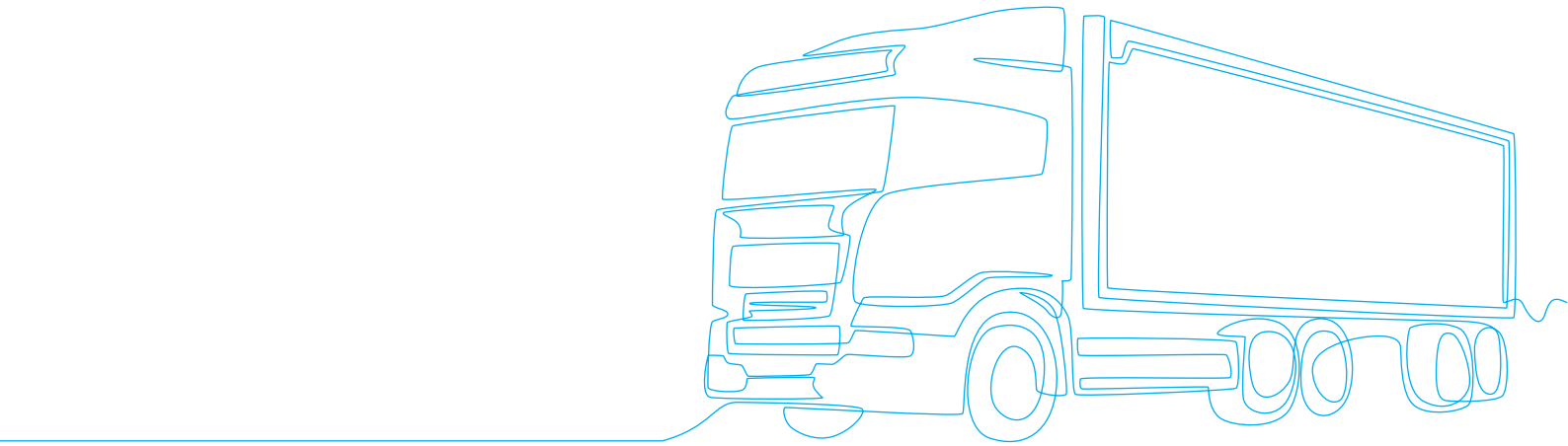
Industry efforts are also underway to establish techno-commercial viability of retrofitted trucks in the Indian context. At the 2023 India Energy week in Bangalore, Reliance Industries Limited (RIL) in partnership with Ashok Leyland launched India's first Hydrogen Internal Combustion Engine (H2-ICE) powered heavy duty truck. While the efficacy andtechno-commercial viability of such proposed retrofits are yet to be proven, the company claims that this could be a faster and lower cost way to switch to clean energy.[152]

As a first step under the plan, Leyland will retrofit an existing fleet of 45,000 trucks (which RIL has contracted to ferry refined products and other marketing goods) with fuel-cell engines so that these vehicles can use green hydrogen instead of diesel. If successful, this proof of concept can lay the foundation for scale up.[153]

Challenges in the Transition to Zero Emission Trucks in India

As India moves forward with a freight electrification strategy, cross-learnings from other markets will need to be balanced with India's ownership and operating model. Considerations for India's ZE freight development strategy are below.

- **Upfront costs & truck fleet ownership patterns pose economic barriers for ZET adoption:** A recent assessment by Niti Aayog acknowledged that ZETs are approximately 2.5 to 6 times costlier than the diesel trucks, depending on the tonnage capacity.[154] There are often operational savings, though payback periods can range between 6 to 18 years for MDVs and HDVs, respectively. Thus, purchase incentives for ZETs would be key for fleets to transition to ZETs. Such incentives must consider that the market is highly fragmented: an estimated 55% of truck buyers are individuals, and 70% of truck fleets are small fleet operators with less than six trucks.[155] Individual owners or smaller fleets will likely face increased financing and economic barriers to electric truck adoption. To transition to ZE MDVs and HDVs, it is necessary to engage with stakeholders to identify strategies and to support increased collaboration and organization. Incentives, awareness, and other demand-side policies will also likely be key to send OEMs demand signals sufficient to promoting e-truck R&D and investment.
- **Lower profit margins of Indian truck OEMs restrict their ability to invest in advanced technologies:** Conversations with Industry stakeholders highlight that Indian OEMs tend to operate at an EBITDA margin (a profitability ratio that measures how much earnings a company is generating before interest, taxes, depreciation, and amortization, as a percentage of revenue) of less than 10%, compared to 12-15% by US & European OEMs. This curtails the ability of Indian OEMs to invest aggressively in alternate fuel technologies.
- **Indian use cases and operating conditions warrant greater optimization with respect to total cost of ownership:** Almost one third of the medium- and heavy-duty truck fleet in India is prone to 50-70% cargo overloading above Gross Vehicle Weight Rating (GVWR).[156] This propensity for overloading can reduce battery performance and vehicle range, and negatively impact ZET total cost of ownership performance. Greater optimization for ZETs could help cater to Indian use cases.
- **Electricity transmission and distribution poses a significant challenge to ZET deployment:** The average loading and unloading time for trucks in India ranges from around 4-6 hours, implying that they spend significant time at their start depots & destination points. Here overnight and loading area charging can greatly reduce charging costs for ZETs. However ZETs usually travel long distances and require high-power chargers that may significantly increase demand on grid capacity. For instance, charging stations on a highway servicing twenty MDVs and HDVs and ten cars with fast chargers could experience peak electricity demand of about 20 megawatts, equivalent to the power consumption of a city with 20,000 residents.[157] Substantial investments in electricity transmission and distribution networks can help meet the power demands of ZE MDVs and HDVs. India is taking big strides forward to strengthen its transmission network with greater integration with renewables: last year, the Ministry of Power approved the transmission system plan for integration of over 500 GW of renewable energy capacity by 2030, with additional systems upgrade plans underway. [158] Going forward, more investment on the distribution front would also help pave the way for additional ZET deployment.



Recommendations for accelerating deployment of Zero Emission Trucks in India

India currently imports more than 81 percent of its oil: of the total petroleum consumed by the transport sector, nearly 60 percent is consumed by freight trucks.[159] Embracing ZETs presents a unique opportunity for India to reduce its oil import associated GHG emissions.[160]

Based on a review of best practices, research, as well as stakeholder consultations with ecosystem players across the value chain, we present key recommendations to accelerate freight electrification in India.

Demand-side policies such as purchase subsidies, feebates, interest subvention, scrappage incentives, zero-emissions zones, and fleet purchase requirements can prove to be critical is establishing the larger value proposition for fleets to convert to ZETs. On the supply side, policy levers such as ZET credit schemes, ZET production targets, air quality regulations, and fuel efficiency standards can provide the much-needed push to OEMs to invest more into zero emission technologies. Supply-side policies have been the most effective regulatory tool used globally and have been the driving force behind sustained ZET adoption in the United States and Europe. With the right implementation of demand & supply side levers, India is primed to become a global leader in clean freight transportation.

A combination of short- and long-term targets would help provide a clear roadmap for both immediate actions and the overall direction of the industry. Short-term objectives can focus on incremental improvements and technology adoption, while long-term objectives can drive transformative changes and innovation. At a macro level, defining a clear target number or share of ZE MHDV sales or stock would have significant impact. Clearly defined targets could give OEMs the confidence to invest in research, development, and production of vehicles that align with future market demands and regulatory requirements. The targets setting process could follow a scientific and consultative approach with OEMs, fleet operators, energy service providers alongside adequate due-diligence on techno-economic feasibility and global market developments.

DEMAND SIDE POLICY LEVERS THAT CAN SUPPORT ZETS TRANSITION IN INDIA

Potentially beneficial demand side policy levers include fiscal and non-fiscal incentives, regulatory mandates that aim at demand aggregation, bringing down the upfront cost, improve operational viability and ultimately increase the uptake of ZETs.

- **Purchase subsidies:** Governmental EV policies have been providing a range of incentives to reduce the upfront cost of owning an EV. These incentives include exemptions from road tax and registration fees, reduced vehicle financing interest rates, income tax rebates, etc. Purchase incentives to reduce upfront costs are one of the most powerful tools to achieve cost parity with ICE vehicles and drive the adoption of ZE vehicles in the short run. As highlighted above the biggest deterrent to adoption of ZETs is their high upfront costs, as they are almost 2.5 to 6 times more costly than their diesel counterparts depending on their load capacity. Extending purchase incentives to MDTs and HDTs can reduce the price differential and improve the total cost of ownership making a business case for fleet operators looking to adopt ZETs. Such subsidies can generate demand during the market ramp-up stage. These incentives can be phased out as manufacturing costs drop through economies of scale and market forces take over.
- **Feebates to incentivize ZETs & dis-incentivize ICE trucks:** To help offset the costs of subsidizing ZE MDVs and HDVs, a revenue-neutral “feebate” program that levies a fee on highly polluting ICE vehicles and uses those funds to subsidize the costs of greener MDVs and HDVs can be explored. This could create a self-financing mechanism, thereby diminishing the need to use public funds. Some of the options India can look at include additional fuel cess, pollution cess, higher toll charges, higher permit charges to help disincentivize diesel. For instance, The National Highway Authority of India (NHAI) could work with road concessioners to design and carve out an exemption from toll taxes for ZE MDVs and HDVs. Policies like the EU directive that provides up to 75% toll discounts to ZE MDVs and HDVs and other vehicles on the trans-European road network could be considered. The toll

discounts could be pegged to the CO_2 emission levels of the vehicle. ICE vehicles can be charged higher tolls to offset the loss of revenue incurred due to toll exemptions/discounts offered to ZE vehicles. Indian states could consider adopting exemption policies for ZE MDVs and HDVs at state tolls within their jurisdiction.

- **Scrappage incentives:** The existing national Vehicle Scrapping Policy mandates scrappage of commercial vehicles, including trucks older than 15 years if they fail to pass the fitness test. Per the policy, a consumer is provided a scrap value on de-registration of an old vehicle, and an upfront discount and motor vehicle tax rebate on purchase of any new vehicle.[161] Higher scrappage incentives can be considered for customers buying ZETs and could fastrack the objective of eliminating polluting diesel trucks from Indian roads.
- **Credit guarantees, risk sharing & Interest subvention for financing ZETs transition:** Currently perceived technology, business model and market risks are barriers to financing for EVs. This gets more complex when it comes to MDVs and HDVs. Regulators, in collaboration with development finance institutions, can consider providing credit guarantees, establishing risk sharing mechanisms in case of default and providing cheaper financing at least to support initial demonstration pilots over next three to five years.
- **Purchase targets for fleets:** Demand for ZETs could be stimulated by establishing purchase targets for fleets. These targets can be codified into a law something similar to California's Advance Clean fleet (ACF) ACF regulation. Like the ACF regulation, Indian states could set purchase targets by requiring fleet owners to purchase more ZE MDVs and HDVs year-on-year. This could also serve as an effective demand signaling for OEMs to strategize their investments.
- **Getting highways ZET ready:** Availability of adequate charging Infrastructure is one of the key requirements for accelerated adoption of EVs, and electric trucks are no different. EV policies could consider incentivizing (through research and innovation, purchase and installation, and connection to the grid) charging infrastrucutre buildout to support pilot projects, as that can help build confidence and scale.[162] Regulators can play a critical role by incentivizing and supporting investments in electrical infrastructure upgradesthrough policies, grants, tax incentives, or regulatory frameworks that encourage grid modernization. Funding to help address the upstream infrastructure costs of installing high-capacity chargers could also be considered. Further capital incentives could also be provided for fleet owners to deploy fast chargers to charge their own vehicles at depots and major hubs, with differential rates based on charging demands and time of use.
- **Non-fiscal incentives:** Provisioning for zero-emissions zones (ZEZs), waiving entry restrictions (and thus providing unrestricted access) for ZETs , and restricting polluting diesel trucks entry on congested routes during specific hours of the day can prove to be effective operational advantages for fleet owners to transition to ZETs.

SUPPLY SIDE POLICY LEVERS THAT CAN SUPPORT ZETS TRANSITION IN INDIA

Through PLI schemes and EV policies, India has been incentivising the development of a robust manufacturing ecosystem for EVs and its components. At this point, expanding existing policies, tightening regulations, and developing newer policy levers are key to facilitate the ZETs transition.

- **Tightening of fuel emission standards can nudge OEMs to shift to ZETs:** Fuel consumption standards for heavy-duty vehicles with a GVWR of 12 tonnes or more were established in 2018. The standards were implemented in two phases (Phase 1 was effective starting in 2018 and Phase 2 was effective 2021). The standards were based on the vehicle's axle configuration and GVWR of the vehicle.[163] In April 2020, similar regulations were put in place for light- and medium duty vehicles with a GVWR of 3.5–12 tonnes.[164] Further regulators can look at fleet wide average fuel efficiency/CO_2 standards for MDVs and HDVs, similar to the passenger cars policy, to allow OEMs the flexibility to innovate and develop more ZE MDVs and HDVs to meet the regulatory requirements. If the standards are made progressively stricter, deploying more ZE vehicles will eventually become a more cost-effective way to ensure compliance than making improvements to internal ICE trucks.
- **ZET sales target for accelerated adoption:** Targets requiring OEMs to achieve an increasing number of ZE sales year on year can help stimulate supply of ZETs in the market. Here California's ACT regulation is a great example of a well-designed regulatory framework that aims to stimulate the supply of ZE MDVs and HDVs and can serve as a model for Indian regulators to gradually ramp up the adoption of ZE MDVs and HDVs. Such policies can stimulate OEMs to set production targets to achieve specific adoption timelines. Several countries/states including Austria, California, Cape Verde, have already established their own ZET targets.[165]

- **ZET credits, market-based approach to incentivize early adopters:** Like the California ACT regulation, regulators can look at adopting a credit-deficit system, to support the industry increasing investment in research and development of electric models. To earn credit, OEMs must sell a certain number of ZETs or purchase credits to fulfill the quota from a ZET manufacturer, which can be increased over time. Rewarding the first movers for selling more ZE MDVs and HDVs & allowing them to trade excess credits can prove to be a highly effective approach. Like the ACT regulation, the credits and deficits could be accounted for based on GHG footprint and vary with vehicle class. India's market-based Perform Achieve Trade (PAT) scheme involves a similar market mechanism for exchanging credits (EScerts) across high-emitting industries and has already successfully reduced emissions in regulated industries.[166]

- **Setting unified charging infra standards for electric trucks:** The success of electric truck adoption heavily relies on the availability of efficient and powerful charging solutions that meet the unique requirements of commercial vehicles. The Ministry of Power has announced plans to deploy at least two fast charging stations (of a minimum of 100 KW each) for MDVs and HDVs every 100 km along highways.[167] Electric trucks often require higher power charging solutions compared to light-duty electric vehicles due to their larger battery capacities and greater energy demand. Higher power charging systems, such as those delivering 350 kW, 900 kW, or even higher, are essential to minimize downtime and enable efficient fleet operations. The existence of multiple charging standards can lead to fragmentation and compatibility issues. Harmonizing hardware and software standards is crucial to enable a seamless and interoperable charging experience, regardless of location or vehicle manufacturer.[168] Standardization not only ensures interoperability but also helps drive down costs. By establishing consistent charging protocols, the industry can achieve economies of scale in manufacturing both trucks and chargers, making electric trucks more cost competitive. A unified and powerful charging network is essential to realizing the full potential of electric trucks and ushering in a sustainable and efficient era of commercial transportation. As the Union Minister of Road Transport and Highways suggested, developing an electrified highway system (such as Germany's catenary system discussed earlier) could also be explored as a potential pathway to decarbonize long-haul trucking.[169] These sorts of innovative strategies could be explored with small pilot programs and cost/benefit analyses. For any such innovations, it is important to assure there is coherence among different policies, to avoid duplication or unnecessary public expenditures.

CONCLUSION

In summary, as India moves forward with truck electrification, a comprehensive regulatory framework for electric trucks in India should encompass a combination of incentives, mandates, standards, and infrastructure development to address various challenges and capitalize on opportunities. A well-crafted regulatory environment can create a dynamic ecosystem that accelerates the transition to cleaner and more sustainable freight transportation solutions.

The electrification of freight trucks is not just a policy endeavor; it's a collective journey that calls upon the expertise, creativity, and determination of policymakers, industry leaders, researchers, and citizens alike. By harnessing the lessons learned from successful regulatory interventions and industry partnerships, we can shape a future where zero-emission freight trucks play a pivotal role in achieving our ambitious climate and air quality goals. India's leap from Bharat Stage IV (BS IV) emission standards to BS VI serves as evidence that transformative shifts are possible, and this principle can certainly be applied to the transition to electric trucks. India's experiences in crafting policies for the electrification of MDVs and HDVs could indeed serve as a valuable template for other countries facing similar challenges. Sharing best practices and lessons learned can accelerate global efforts toward sustainable transportation.

Annexure

Compendium of International Medium- and Heavy-Duty Freight Electrification Policies and Programs

Region/ Country	Scope of policy/ regulation	Brief Description	Launch date
Target Setting & Regulatory Requirements			
Austria	National	Austria has announced a national Mobility Master Plan, which sets targets to end the sale of conventional MHDVs under 18 tons by 2030 and by 2035 for those over 18 tons	2021
Canada	National	Canada aims to have 35% ZEV sales by 2030 and 100% ZEV sales by 2040 for a subset of vehicle types based on feasibility	2022
China	National	China has established a target to fully electrify its public sector vehicles (comprising buses, sanitation vehicles, postal vehicles, urban logistics vehicles, and other types) by 2035, as outlined in its New Energy Vehicle Industry Development Plan (2021-2035)	2021
Chile	National	Chile announced its National Electromobility Strategy targets of 100% ZE MHDVs sales by 2045	2022
Netherlands	National	Under the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles, Netherlands has committed to a 30% share of new trucks and buses to be zero emission by 2030 and 100% by 2040.	2021
Norway	National	Norway has a target of ensuring all new heavier vans and goods distribution vehicles used in the biggest city centers, and 50 percent of new trucks, be ZEVs by 2030.	
United Kingdom	National	The United Kingdom has a target of phasing out non-ZE Heavy Goods Vehicles (HGVs) less than or equal to 26 tons by 2035, and all new non ZE HGVs sold in the UK by 2040.	
USA	State-level	California Advanced Clean Trucks (ACT): The ACT regulation prescribes that manufacturers of MHDVs sell ZE trucks as an increasing percentage of their annual California sales starting from the 2024 model year. California (+ six other US states— Maryland, Massachusetts, New Jersey, New York, Oregon, and Washington—have adopted this rule)	2020 (comes into effect from 2024-2035)
USA	State-level (California)	Advanced Clean Fleets (ACF) regulation stimulates demand for ZE commercial vehicles by requiring large private and public fleet owners to purchase an increasing percentage of ZE MHDVs over time.	2023
Vehicle Emission Standards and Fuel Efficiency Standards			
China	National	Implementation Plan for Synergistic Reduction of Pollution and Carbon Emissions launched by Ministry of Ecology and Environment	2022

Region/ Country	Scope of policy/ regulation	Brief Description	Launch date
European Union	Regional	Proposed revision to EU CO2 Regulations: The standards are projected to reduce cumulative emissions from trucks and buses by 1.8 billion tons of CO2 by 2050, amounting to a 64% reduction in annual emissions by 2050 relative to 1990.	2023
USA	National	US EPA adopted revised clean air standards for heavy-duty vehicles in December 2022. The standards are expected to result in a 48% reduction in nitrogen oxide, a 28% reduction in benzene, a 23% reduction in volatile organic compounds, and an 18% reduction in carbon monoxide emissions from heavy-duty vehicles by 2045	2022
USA	National	PROPOSED: U.S. EPA proposed the next round of GHG emission standards (Phase III) for heavy-duty trucks for model year 2027 and beyond.	Emission standards expected to come into force by end of 2023.
Purchase Incentives			
Austria	National	Emission-free Commercial Vehicles and Infrastructure (ENIN) funding program supports companies in converting their fleets to non-fossil-powered commercial vehicles and in setting up the charging and refueling infrastructure required for these commercial vehicles. Through the European Union's Recovery and Resilience Facility (RRF) and other national funds, Austria has a total of €365 million available to promote zero-emission commercial vehicles and their infrastructure.	2022
Belgium	National	Under the Ecology Premium+ program, the support for battery electric trucks is doubled by compensating 80% of the cost difference with a conventional truck. In addition to other conditions, each company can have a maximum of 2 trucks funded under the program.	2023
China	National	In 2020, China released its revised subsidies policy for promoting sales of both commercial and passenger class NEVs including trucks. The decade-long policy providing purchase incentives to stimulate the growth of NEVs was extended until the end of 2023.	2020
Croatia	National	Fund for Environmental Protection and Energy Efficiency is providing co-financing of energy-efficient vehicles, including EVs. For vehicle categories N2 and N3, EVs are supported with a maximum of HRK 400,000 per vehicle (approx. €53,000).	
Czech Republic	National	The Czech subsidy program 'Výzva č. 3/2022: Ekomobilita' (Call No. 3/2022: Ecomobility) has a budget of 600 million CZK (approx. €25 million) and offers purchase incentives for battery electric trucks (>12t).	
Denmark	National	The 'Implementation pool for green transport' program offers funding to hydrogen and battery-electric trucks compensate for 60% of the price difference with a diesel vehicle for small enterprises and 40% for large organisations.	2021
Finland	National	Purchase support is available for electric trucks, trailers and gas-powered trucks with a maximum subsidy of €50,000.	2022

Region/ Country	Scope of policy/ regulation	Brief Description	Launch date
France	National	France is providing 40% of the purchase cost of ZE HDV up to EUR 50,000.	2021
Germany	National	Germany is providing up to 80% of the price differential between ZE HDV and Euro VI diesel equivalent models.	
Malta	National	The 'Schemes for more sustainable transport' provides funds for purchase of electric heavy duty vehicles with up to a maximum of €250K depending on the enterprise's size, equaling 40% of the costs.	2022
Netherlands	National	The AanZET program provides subsidies for purchase of ZETs capped at 40% of the vehicle costs on average.	2022
Sweden	National	Subsidy support of maximum of 40% of the cost gap with a conventional diesel truck with a capping at a maximum of 20% of the purchase price of ZET.	2022
UK	National	UK government is providing plug-in truck grants (PITrG) to reduce the purchase price of HGVs by 20%, with up to £25,000 of funding available for trucks heavier than 12 tons.	2022
USA	National	U.S. Inflation Reduction Act provides tax credits of up to USD $40,000 or 30% of the vehicle cost, whichever is lower, for all-electric commercial vehicles greater than 14,000 lbs	2022
USA	State-level (California)	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP): Funded by California's Cap and Trade carbon program, HVIP provides point-of-sale vouchers of up to USD $375,000 per vehicle to make advanced vehicles more affordable. A pilot project under HVIP reserves $25 million exclusively for helping small trucking fleets and independent owner-operators access ZE trucks.	2009
USA	State-level (California)	Truck Loan Assistance Program: helps small-business fleet owners who don't meet tradition lending criteria secure loan financing for upgrading their fleets with newer clean trucks.	2009
Charging Infrastructure			
Austria	National	Emission-free Commercial Vehicles and Infrastructure funding program supports companies in converting their fleets to non-fossil-powered commercial vehicles and in setting up the charging and refueling infrastructure required for these commercial vehicles. Through the European Union's Recovery and Resilience Facility (RRF) and other national funds, Austria has a total of €365 million available to promote zero-emission commercial vehicles and their infrastructure. For trucks (above 80kW), a contribution of €30,000 is offered under ENIN.	2022
Belgium	National	The Ecology Premium+ program also covers the premium to enables the construction of recharging stations compensating up to 30% of the costs as long as the power output is at least 50 kW and renewable energy is used.	2023

Region/ Country	Scope of policy/ regulation	Brief Description	Launch date
China	National	Implementation opinions on further improving the service guarantee capacity of electric vehicle charging infrastructure: The policy supports highway fast charging by committing to 80% coverage rate of fast charging stations on highways, national ecological civilization pilot areas and key areas for air pollution prevention and control—with other areas meeting at least 60% coverage by 2025. It also supports construction and layout of dedicated battery swap stations in areas such as mines, ports, and urban transshipments.	2022
Denmark	National	The 'Implementation pool for green transport' program has set aside funds to study the possibilities for overhead catenary lines on the Øresund-Femern belt.	2021
EU	Regional	Alternative Fuel Infrastructure (AFIR Regulations) regulations set mandatory deployment targets for electric recharging and alternative fuel (hydrogen, liquified methane) refueling infrastructure for cars, trucks, ships and planes across the EU	2023
France	National	The Advenir program aims to fund the setting up of 1000 new charging points for HDVs.	
Germany	National	The KsNI program provides funding for setting up fast chargers for cars and trucks.	2021
Spain	National	The fleet transformation program provides support for installation of charging infrastructure for heavy vehicles with up to a maximum of 60% of the eligible costs basis the power capacity of the charging point.	
USA	National	Infrastructure Investment and Jobs Act 2021 invests USD $7.5 billion to deploy a nationwide network of 500,000 EV chargers by 2030	2021
USA	National	Inflation Reduction Act provides tax credits of up to USD $100,000 or 30% of the cost per charger, whichever is lower, for alternative fuel vehicle refueling infrastructure for ten years through 2032	
USA	State-level (California)	Low Carbon Fuel Standard (LCFS), the California Energy Commission's (CEC) Clean Transportation Program, and the California Public Utilities Commission's (CPUC) investments in MHDV charging infrastructure all aim for accelerated investments in developing charging infrastructure by providing tax credits under LCFS, by direct investments under CEC's program and through utilities' investment through CPUC programs	

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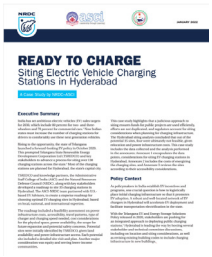
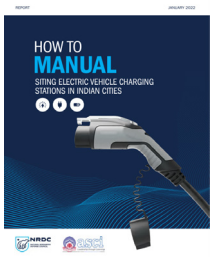


Ready to Charge Siting Electric Vehicle Charging Stations in Hyderabad



How to Manual Sitting Electric Vehicle Charging Stations in India

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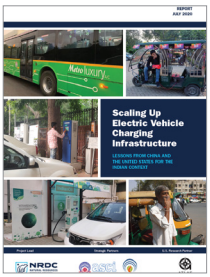

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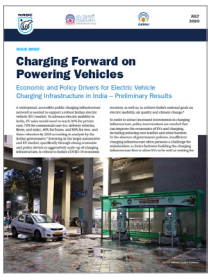

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