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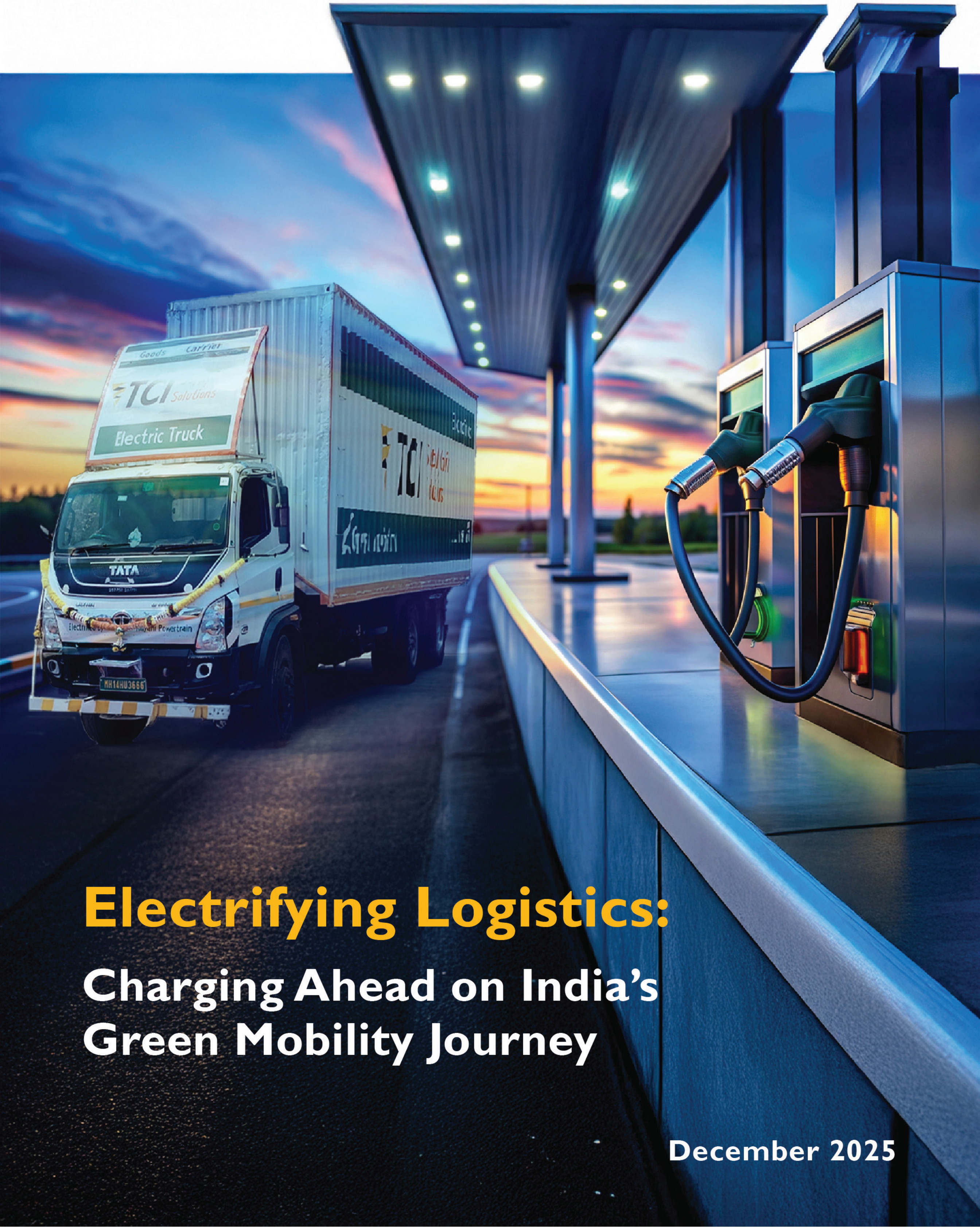

Electrifying Logistics:

Charging Ahead on India's Green Mobility Journey

December 2025

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Foreword

As India accelerates toward its vision of a low-carbon, resilient and globally competitive economy, the transformation of its logistics and freight ecosystem has become both an environmental imperative and a strategic opportunity. With road transport carrying nearly 70% of the nation's freight, logistics sits at the heart of India's growth story and equally, at the centre of its decarbonisation challenge. The transition to electric mobility, particularly across commercial vehicles, is no longer aspirational; it is rapidly becoming foundational to the future of Indian logistics.

This edition of Logistics Focus, titled **"Electrifying Logistics: Charging Ahead on India's Green Mobility Journey,"** explores how electric vehicles, charging infrastructure and enabling ecosystems are reshaping freight movement across the country. As electric small, medium, and heavy commercial vehicles gain traction, the spotlight shifts decisively to charging infrastructure—its readiness, scalability and ability to support high-utilisation, time-critical logistics operations. Charging is no longer just a technical enabler; it is a determinant of fleet economics, operational efficiency, and adoption speed.

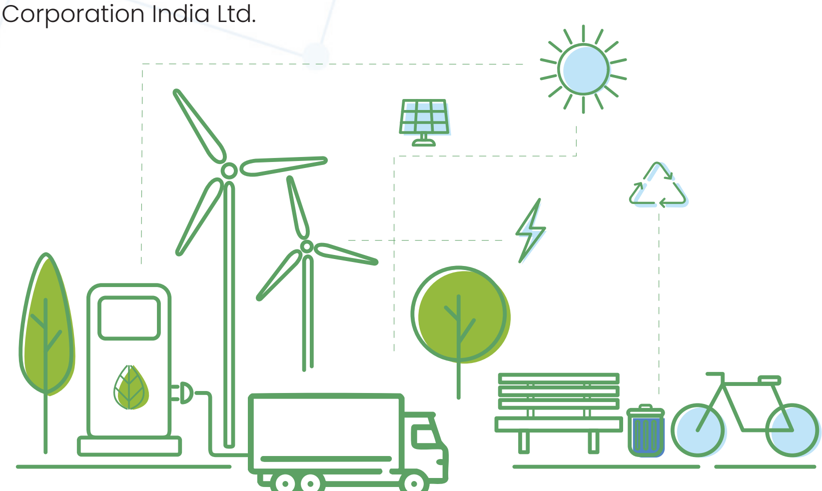
The articles in this edition examine the evolution of EV adoption in logistics, the rise of electric SCVs in urban and mid-mile operations, and the critical role of high-power charging networks for medium- and heavy-duty vehicles. They also assess emerging business models, policy frameworks, and corridor-based approaches that can unlock large-scale electrification while addressing grid constraints, land availability, and cost pressures. Together, these perspectives highlight the need for coordinated planning across vehicles, infrastructure, energy systems, and digital intelligence.

As India moves toward its net-zero commitments and a cleaner freight future, the choices made today—by policymakers, industry leaders, infrastructure developers, financiers, and fleet operators—will define the pace and success of this transition. This edition offers insights into how India can build an electric-first logistics framework that balances growth with sustainability, innovation with practicality, and ambition with execution.

We hope this issue serves as a valuable reference for all stakeholders working to electrify India's logistics backbone and drive the next phase of green mobility.

Happy Reading!

Marketing Communications Team
Transport Corporation India Ltd.



India's Green Logistics Future Will Be Built on the Shoulders of Electric SCVs

- By Saju Nair, CEO – eSCV, Montra Electric

MONTRA ELECTRIC

India's logistics sector is entering a defining phase of growth. Valued at $228.4 billion in 2024 and projected to reach nearly $428.7 billion by 2033, it is now among the fastest-expanding logistics markets globally. This surge is being powered by rising consumer demand, faster goods movement, and an economy that increasingly runs on speed and reliability.

But this growth is also deepening one of the sector's biggest structural dependencies, road transport. Nearly 70% of India's domestic freight continues to move by roads, making it the backbone of the logistics economy and, simultaneously, one of the largest contributors to its carbon emissions. As expectations around environmental responsibility rise alongside operational performance, growth and sustainability are no longer separate conversations, they now intersect in every strategic decision.

India's logistics engine is strong, but it continues to rely heavily on a fuel that no longer aligns with our economic or environmental goals, which is Diesel. Of the 500,000+ SCVs sold annually, almost 4.5 lakh still run on diesel, highlighting the scale of transition required. The question is not whether logistics will grow, but how it will grow without multiplying its emissions footprint.

And the answer is becoming clear: India's green logistics revolution will not be triggered by one technology, one policy, or one dramatic leap. It will happen through hundreds of daily decisions made by fleet managers, and the Small Commercial Vehicle (SCV) segment will lead this shift.

A Shift in What Logistics Leaders Expect from Their Fleets

Not too long ago, fleet strategy centred on cost per kilometre, load efficiency, and the ability to manage seasonal fluctuations. Those factors still shape decision-making, but they no longer stand alone. Logistics partners are now asked for emissions visibility. Large enterprises want cleaner supply chains. Cities are searching for ways to reduce pollution and noise. International brands include sustainability criteria in vendor selection.

This shift is part of a global conversation. Logistics and freight operations contribute roughly 7% of greenhouse-gas emissions worldwide. At the same time, demand for freight continues to grow. Between 2000 and 2015, global freight activity increased by nearly 68%, and the upward trend continued into the next decade. As more goods travel longer distances, the environmental footprint grows with them.

In India, these pressures feel even more immediate. Diesel prices fluctuate often enough to affect margins within the same quarter. Congestion in major cities makes it harder to run predictable operations. Air-quality concerns are part of everyday life. With these realities in mind, cleaner fleets are being viewed not as a symbolic commitment but as a practical step toward stability and future readiness.

Electric Vehicles Are Becoming the Backbone of Urban Logistics

Electric mobility has begun to settle naturally into India's logistics ecosystem. The transition did not rely on one large push. It happened through steady adoption and real-world testing. Companies placed electric vehicle for mid-mile and last-mile transportation, monitored performance, and realised the technology aligned surprisingly well with daily delivery patterns.

EVs work particularly well for last-mile and mid-mile operations because these routes are predictable. Vehicles travel within a known radius and return to a depot by the end of each shift. This allows operators to plan charging cycles and track energy use with accuracy. In many cases, the cost of running an electric drivetrain is significantly lower than powering a diesel vehicle through a day of stop-and-go deliveries.

These vehicles offer strong cargo capacity, easy manoeuvrability, and lower operating costs. They also help ease congestion and reduce noise in dense areas. In several Indian cities, it is now common to see electric vehicles carrying everything from food and electronics to pharmaceutical supplies.

The energy ecosystem around EVs has also evolved. More companies built private depot charging. Telematics tools matured, giving fleet managers better visibility into battery health, route performance, and energy consumption. These changes made EV adoption feel grounded, not experimental.

India Is Moving Toward an Electric-First Logistics Framework

Logistics in India is too diverse for a single, rigid model, but one trend is unmistakable: Electric SCVs will dominate last-mile and mid-mile logistics.

This EV-first framework is taking shape because it aligns seamlessly with the realities of India's freight ecosystem such as predictable route lengths, depot-based operations, high utilisation rates, rising fuel costs, and increasing environmental scrutiny.

Electric SCVs sit at the intersection of all these forces, making them the most adaptable segment for rapid, large-scale EV adoption.

The EV Adoption Curve Is Strengthened by Three Transformations

The EV adoption curve is being strengthened by three major transformations shaping the future of electric logistics in India. Together, these shifts are creating the right economic, operational, and technological environment for rapid EV deployment across commercial fleets, especially in the SCV segment.

The first transformation is the **evolution of India's charging ecosystem,** which has become far more operator-friendly than even a few years ago. The early debate around EV adoption centred heavily on charging availability, but that concern is steadily fading. Today, India has fleet-dedicated depot charging, high-capacity private chargers inside logistics parks, fast-growing public charging networks, micro-charging clusters around warehousing hubs, and smart charging systems that minimise peak-load stress. For SCV operations, where routes and duty cycles are predictable, the charging question has effectively been solved through planned depot-based charging rather than dependence on public networks.

The second transformation is the **emergence of digital intelligence** as a core differentiator in fleet operations. Electric SCVs come embedded with advanced telematics and connected tools that were once optional in ICE fleets. Fleet managers can now track energy use per trip, monitor driver behaviour, receive predictive maintenance alerts, assess battery health and charging patterns, and optimise routes with real-time insights. This level of visibility not only improves uptime but also enables logistics companies to achieve 10–15% efficiency gains without expanding fleet size. EVs are no longer just cleaner, they are smarter, enabling tighter, more responsive operations.

The third transformation is the leap forward in **battery technology,** which has significantly enhanced the performance and reliability of electric SCVs. Recent advancements include higher-density LFP battery packs, improved thermal management, longer lifecycle durability, stronger performance in stop-start driving conditions, and faster, safer charging capabilities.

These improvements have made modern electric SCVs fully capable of handling 1–1.5 tonne payloads, navigating gradients, and operating for extended hours, delivering performance levels that fleet operators once expected only from diesel vehicles.

The Supporting Ecosystem Will Determine the Pace of Adoption

Technology alone cannot transform logistics. The supporting ecosystem will play an equal, if not greater, role. Digital tools have become essential. Operators now depend on telematics to track energy consumption, route performance, and battery health. These insights help companies reduce operational waste and plan transitions more effectively.

Innovative Financing Models by Banks and NBFCs are evolving with EV-specific products, covering battery financing, leasing models, and utilisation-linked repayment.

Training and workforce development play an equally large role. Drivers and technicians require new skill sets such as EV safety, charging discipline, predictive diagnostics. Companies investing in skilling see smoother adoption and higher uptime.

Depot charging, energy partnerships, and standardised protocols will shape the speed of transition. The early signs are clear: collaboration accelerates adoption.

The Competitive Advantage Belongs to Early Adopters

Companies that shifted early toward cleaner fleets have already begun to see financial and brand benefits. Lower fuel costs, reduced maintenance expenses, stronger ESG alignment and greater customer trust have become visible advantages. Several procurement teams now prefer logistics partners that bring low-emission solutions to the table.

With India's logistics market on track for significant expansion, the value of early adoption will only increase. Clean mobility is becoming a marker of operational maturity.

A Defining Decade for India's Logistics Sector

Electric SCVs are redefining how India thinks about logistics.

They do not merely reduce emissions, they reshape economics, operational certainty, and fleet intelligence.

India's freight demand will continue rising. Expectations around sustainability will rise alongside it. Companies that recognise this shift today and build electric-first fleets will set the benchmark for India's next decade of logistics excellence.

Green logistics is not arriving through disruption. It is emerging through steady, thoughtful adoption led by operators who understand where the industry must move.

Disclaimer:

The views expressed are solely that of the author.

Company Profile

Montra Electric, is a pioneering clean mobility brand from the Murugappa Group, one of India's oldest and most respected business conglomerates with a legacy spanning 125 years. Drawing in deep expertise of converting 'Metal to Mobility' earnt with decades of manufacturing high precision automotive and industrial components for India and Global needs; coupled with the track record of creating strong brands, Montra Electric has set on the vision of clean mobility. The Company operates under 4 business verticals - Medium & Heavy Commercial Vehicles, Small Commercial Vehicles, Last Mile Three wheelers and Tractors. The fast-expanding portfolio of Montra Electric consists of the India's first 55 Ton Electric Truck Trailer RHINO, 3.5 Ton Small Commercial Vehicle EVIATOR, Last Mile Passenger Vehicle SUPER AUTO, Last Mile Delivery solution SUPER CARGO and India's first Electric Tractor E-27.

Author Profile :

Saju Nair
(CEO e-SCV, Montra Electric)

Saju Nair serves as the Chief Executive Officer of e-SCV, Montra Electric (Tivolt Electric Vehicles), leading the transformation of urban goods mobility with electric small and light commercial vehicles. With 25 years in the automotive industry, he has held senior leadership roles at Tata Motors, VE Commercial Vehicles, and Piaggio Group, driving product innovation, revenue growth, and customer-first strategies.

Under his guidance, Montra Electric's SCV has become one of the best and gained respect in the EV space by delivering comprehensive solutions that prioritize customer profitability, sustainability, and quality.

Known for a mission-driven leadership style, Saju emphasizes technology-led innovation, customer profitability, and environmental impact. His tone and interviews reflect strategic clarity, collaborative ethos, and sustainability advocacy.

EV charging infrastructure - Developments, Opportunities, and Roadblocks

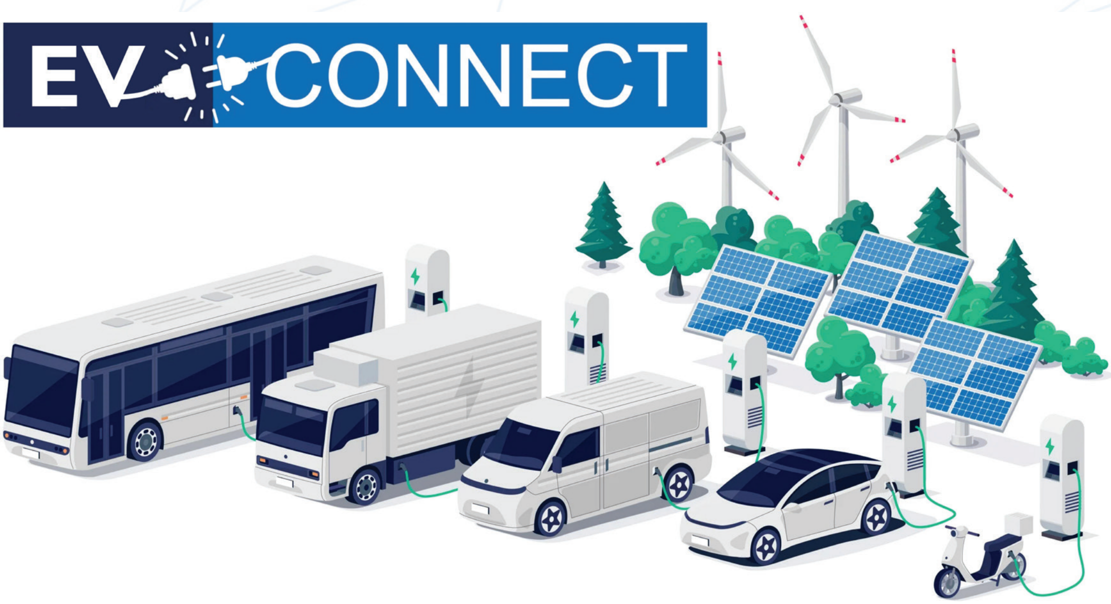
- By Christoph Wolff, Chief Executive Officer - Smart Freight Centre

Introduction

India stands at a defining moment in its transportation and energy transition. Around the world, the race to decarbonize freight is accelerating: the European Union is advancing policies and initiatives like Europe Clean Transport corridor initiatives to accelerate the deployment of heavy-duty vehicles recharging infrastructure across key freight corridors, while China is integrating high-power charging and battery swapping across its industrial logistics backbone. The message from global markets is clear, as TCO parity reaches a growing share of freight segments, **the momentum behind heavy-duty transport electrification is strengthening, and the imperative to scale charging infrastructure is becoming even more urgent.**

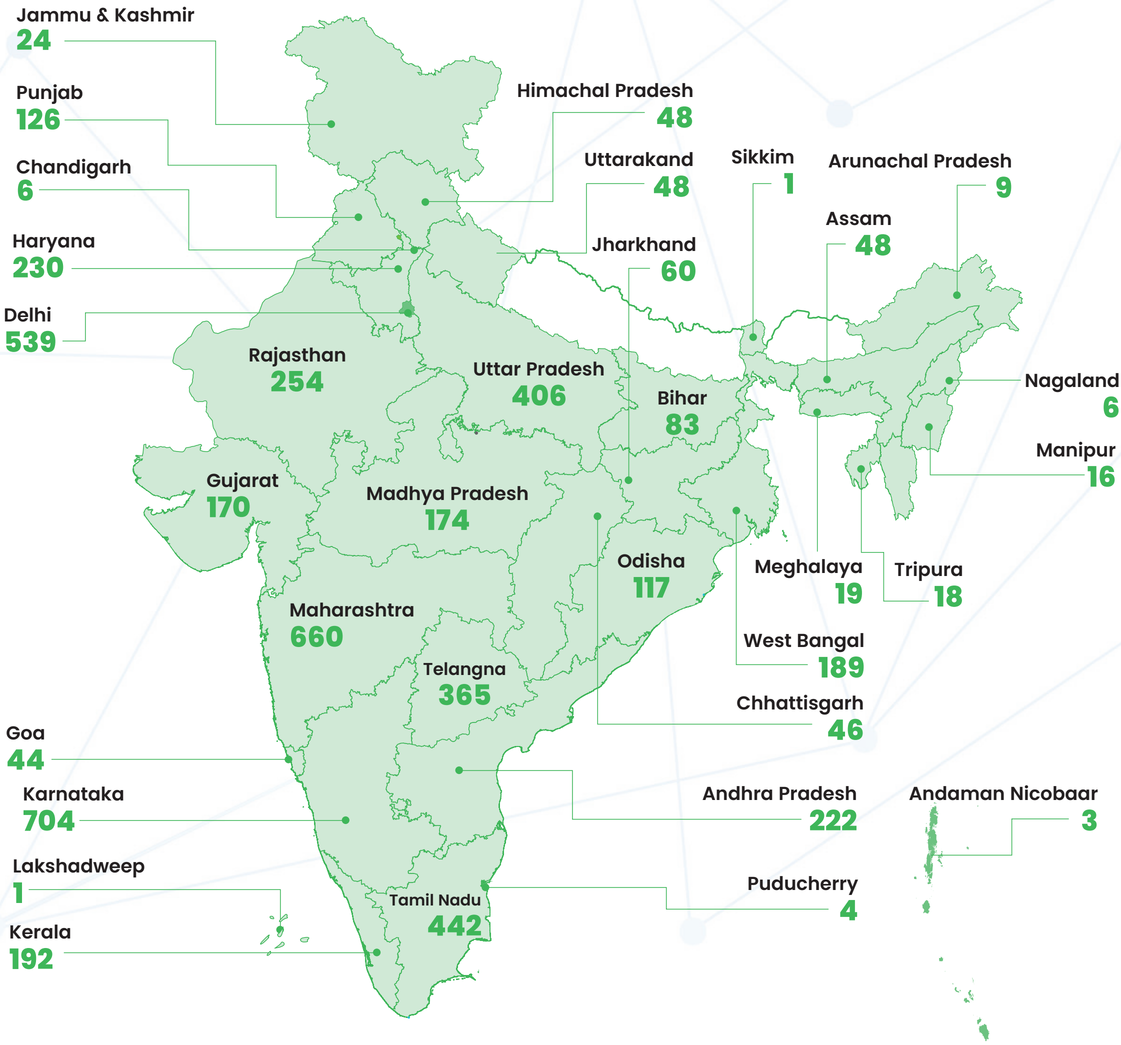
India's commitment to reach net-zero emissions by 2070 places the freight sector squarely at the centre of this national transformation. Trucking already moves nearly **70% of domestic freight,** and demand is projected to **quadruple by 2050** driven by rising consumption, industrial growth, e-commerce, and urbanization. This growth, however, comes with steep economic and environmental costs: if diesel trucking expands unchecked, India could cumulatively spend over USD 1 trillion on crude oil imports for diesel by 2050, deepening an already critical energy-security vulnerability. At the same time, trucking contributes about one-third of transport-related CO_2 emissions, making it one of the hardest-to-abate segments of the economy.

Aligning with global pathways that limit warming to below 2°C will require India to reach **100% zero-emission truck sales by 2050.** International benchmarks reinforce this direction: the EU has mandated a 90% CO_2 reduction for new trucks by 2040, China is rolling out megawatt-class chargers and smart charging at freight hubs, and global OEMs have announced aggressive timelines for electric MHDVs backed by high-power charging ecosystems. These trends converge on one fundamental reality: **to scale ZET adoption, scaling charging infrastructure is the key.**



For India, this means that the deployment of medium- and heavy-duty electric vehicles (MHDVs) must be matched by a rapid rollout of high-power charging solutions to minimize operational downtime and maintain fleet efficiency. MHDVs typically require high-power DC chargers in the range of 120–240 kW and above, and critical freight infrastructure such as national corridors, logistics terminals, ports, warehousing clusters, and designated rest locations must be systematically prepared to support this transition. In essence, the success of India's electric mobility revolution in the freight sector hinges on the timely deployment of robust, well-planned EV charging infrastructure tailored to the unique demands of this high-power, high-utilization segment.

Existing Charging Landscape for MHDVs in India



Source - Ministry of Power, Vahan Dashboard

The deployment of electric medium- and heavy-duty vehicles (MHDVs) and their charging ecosystem in India is evolving backed by a rapidly evolving policy and regulatory framework informed by multiple Indian studies and pilots. As of Oct-2025, around ~1000 b attery electric MHDTs have been registered, largely confined to highly controlled use cases such as cement and steel plants, ports, and dedicated city logistics routes where fleets can rely on depot-based charging. In parallel, India's public charging network has expanded quickly to nearly 30,000–40,000 chargers in the 22–150 kW range, predominantly in urban centres and along major highways, but these assets are designed mainly for 2W/3W and passenger cars and are technically and spatially inadequate for high-utilisation trucks that require minimum 120 kW overnight depot charging and 120–360 kW (and above) fast charging along freight corridors.

Fewer Charge point operators (CPOs) such as ChargeZone with up to 360 kW chargers and Tata-linked networks offering 120–400 kW "mega chargers" on routes like Mumbai– Pune-Ahmedabad, Bangalore-Chennai – Hyderabad, others are beginning to bridge this gap, but these remain isolated efforts rather than a coordinated MHDV strategy. Platforms such as NITI Aayog's e-FAST India program play a critical role in addressing this fragmentation by convening OEMs, CPOs, DISCOMs, shippers, and research partners to align on technical standards, infrastructure planning, and policy direction for zero-emission trucking.

Case Study

SFC Delhi-Jaipur E-truck demonstration run for trucking from 5.5 ton to 55 ton on NH-48 highlights that deploying ultra-fast chargers can reduce transit time by nearly 25% compared to conventional 60 kW stations, materially improving fleet productivity. Moreover, under a 100% public-charging scenario (₹21/kWh, no tariff discount), TCO parity is reached at ~7,600 km/month. Introducing partial depot charging lowers this requirement to ~6,000 km/month, and leveraging renewable-energy-based charging delivers a further 10% improvement, bringing the parity threshold down to ~4,720 km/month.

These findings underscore a critical insight: the economics of electric trucking hinge not just on charger availability, but on deploying the right charging mix, ultra-fast en-route charging for time-sensitive operations, complemented by low-cost depot and RE-integrated charging for energy-intensive applications. The detailed findings can be found here.

Opportunities: Use-Case–Based Charging Mix Strategy: Balancing Swap and High-Power Charging

India's freight ecosystem is highly diverse, and no single charging method can efficiently serve all truck duty cycles, making a **use-case–based mix of battery swapping and high-power wired charging essential.** For fixed-route, high-utilisation operations such as cement and steel plant shuttles, port drayage, and short route e-commerce operations, battery swapping offers a compelling value proposition by enabling sub-10-minute turnaround, decoupling battery ownership from fleets, lowering upfront vehicle costs, and ensuring predictable operations even where grid availability is weak. This mirrors limited but **successful applications seen in China, where swapping has scaled mainly in closed-loop,** industrial segments rather than across the broader trucking ecosystem. However, long-haul and irregular-route MHDVs require high-power DC fast charging (120–360 kW and eventually MW-scale) because battery standardisation, inventory costs, and land requirements for swap stations make swapping impractical at scale for intercity movement. Early International evidence (China's HDV swap networks and U.S.–EU high-power corridors) suggests that swapping thrives in controlled, repetitive-route environments, while fast charging dominates open-road freight. For India, the optimal strategy is therefore a hybrid system: swapping for high-utilisation, repetitive routes where batteries can be pooled, and fast charging for long-haul and corridor-based logistics, ensuring national interoperability, cost optimisation, and scalable infrastructure deployment.

Opportunities: Corridor-Based Charging Deployment: Building High-Utilisation, E-Truck–Ready Highways

India's freight movement is extremely corridor-concentrated, with nearly 50% of road freight moving along just seven major routes, and the Golden Quadrilateral alone carrying almost 40% of national flows. This spatial concentration creates a powerful opportunity to deploy high-power truck charging infrastructure exactly where it will achieve the highest utilisation, economic viability, and investment returns. States such as Maharashtra, Karnataka, Uttar Pradesh, Rajasthan, Gujarat, and Madhya Pradesh expected to account for over 70% of India's e-truck electricity demand by 2050 must therefore be prioritised for early MHDV charging rollout. A corridor-based strategy combines two complementary charging approaches: (1) **Depot charging** in logistics hubs, warehousing clusters, ports, and industrial parks to support overnight or dwell-time replenishment; and (2) **en-route opportunity charging** (≥120 kW, moving toward 240 kW and above) spaced 100 km intervals along national highways, in line with Ministry of Power guidelines. Delivering this vision requires coordinated national and state-level roadmaps that identify priority corridors, forecast segment-wise charging demand, establish land allocation mechanisms, and synchronise DISCOM grid-upgrade plans. The creation of "e-truck-ready highways" and "e-truck-ready zones" with pre-approved land parcels, adequate substation capacity, and streamlined permitting processes would significantly shorten deployment timelines and accelerate ZET adoption.

Smart Freight Centre (SFC) is already applying this approach on the **Bengaluru–Mumbai corridor,** designing an electrification blueprint with optimal charger placement based on projected freight volumes across subsections.

The PSA Top 10 Freight Corridors can serve as an effective starting point for a national strategy. Early market signals are also emerging, with several Charge Point Operators initiating high-power deployments along key corridors such as **Mumbai–Ahmedabad, Mumbai–Pune, Bengaluru–Mysuru, Bengaluru -Chennai–Coimbatore, and Bengaluru–Hyderabad,** demonstrating growing private-sector readiness to support India's transition to zero-emission trucking.

Globally, similar approaches have proven successful: Europe has adopted a **corridor-first, regulation-driven strategy,** mandating high-power truck chargers every 60–100 km under the TEN-T framework, while China has followed a **dual-path model,** scaling battery swapping in closed-loop industrial operations and ultra-fast charging along long-haul freight routes. These international examples underscore that India's corridor-led, mixed-technology approach is both timely and aligned with global best practice

Opportunities: Potential to integrate renewable into charging: Merge with green corridors

India's strong renewable energy (RE) base creates one of the strongest enablers for low-carbon truck electrification globally. According to the **Ministry of New and Renewable Energy (MNRE, 2025),** India has built **over 259 GW of installed capacity from non-fossil fuel sources,** including **129 GW of solar** and **50+ GW of wind,** and generates **over 25% of its electricity from renewables (CEA).** With a national target of **500 GW of non-fossil capacity by 2030.** India is uniquely positioned to power its emerging e-truck ecosystem with clean, low-cost electricity. As RE penetration accelerates in states like Karnataka, Gujarat, Rajasthan, Maharashtra, and Tamil Nadu, e-truck charging hubs can increasingly rely on **solar-PV plus battery storage (BESS) DC microgrids,** which help reduce peak load on distribution networks, enhance reliability, and lower long-term operational costs.

Integrating RE into truck charging dramatically improves **well-to-wheel (WTW) emissions performance.** A battery electric truck charged from India's average grid today already reduces WTW CO_2 emissions by 25–35% compared to a diesel truck. When powered by **100% renewable electricity,** WTW emissions drop by 85–90%, making electric trucks one of the most effective decarbonisation pathways for long-haul freight. This difference is critical because diesel trucks emit heavily not only from tailpipe exhaust but also from the upstream refining and fuel production cycle. RE-powered charging enables India's freight sector to achieve deep decarbonisation even before full grid greening occurs.

Solar-plus-storage charging hubs also strengthen infrastructure economics. Multiple techno-economic studies from India and abroad show that solar- plus-storage and microgrid-based EV charging models can lower lifetime energy costs, reduce dependence on grid imports (and in some cases demand charges), and **improve the long-term economics of charging operations, despite higher initial CAPEX for PV and BESS**.

India's **Green Open Access Rules (MNRE, 2022),** which lowered the minimum eligibility threshold from 1 MW to 100 kW, now allow even medium-sized charging hubs to procure renewable power directly from solar and wind plants, enabling **high-renewable, low-cost, low-carbon truck charging.** Smart charging strategies such as shifting high-power charging to midday solar peaks (as demonstrated in **California Energy Commission** studies), scheduling nighttime charging based on wind availability, and enabling trucks to provide ancillary services further strengthen operational stability and grid harmony.

Early deployments by ChargeZone and Yaahvi Charging in **Dahej and NCR** demonstrate that RE-powered charging hubs are both feasible and commercially attractive, offering cleaner energy at lower tariffs. SFC's trial on the Delhi–Jaipur corridor confirmed that renewable-powered charging enables green tariffs to be passed directly to shippers, improving the TCO of electric freight. Under SFC's ongoing **Bengaluru–Mumbai Freight Electrification initiative (2025–26),** collaboration with renewable developers is identifying optimal, grid-ready, RE-integrated charging locations that maximise cost savings and emissions reductions laying the foundation for India's emerging **Green Freight Corridors.**

Roadblocks and Way forward

Scaling high-power charging infrastructure for medium- and heavy-duty electric trucks presents complex challenges in India and globally, driven by constraints around **power availability, upstream grid readiness, and the high cost of electrical augmentation.** Insights from the Bharat ZET Policy Advisory consultations underscore persistent issues such as voltage instability, unreliable feeder performance, and long timelines for new connections particularly outside metropolitan centres while high-power chargers (120–360 kW and eventually megawatt-scale) impose concentrated loads on distribution networks, heightening risks of thermal congestion, voltage dips, and service outages. Compounding these **technical barriers are financing challenges: early-stage utilisation uncertainty, long payback periods, and substantial upfront infrastructure costs weaken bankability,** with lenders viewing high-power hubs as high-risk assets in a nascent market. CPOs highlighted the absence of utilisation guarantees, slow approval cycles, and unpredictable incentives as key deterrents to investor confidence, underscoring the need for concessional financing, viability-gap support, and structured risk-sharing mechanisms.

For India where MHDV charging demand is projected to reach **~9 GW by 2030** and **171 GW by 2050** a planned corridor-based approach offers the most practical and scalable pathway. This requires synchronised planning across demand and supply: mapping freight intensity, identifying priority highway segments, pre-designating land for charging hubs, and aligning upstream grid reinforcement with projected loads. Integrating renewable energy through open-access procurement, solar-plus-BESS microgrids, and smart charging strategies will further stabilise power availability and lower lifecycle emissions, strengthening economic viability. Global experience consistently shows that such integrated corridor planning coupled with RE-linked charging , standardised permitting, and coordinated infrastructure readiness is essential for building a reliable, efficient, and scalable charging ecosystem capable of supporting the rapid adoption of zero-emission trucking.

In conclusion, the way forward lies in combining smart scheduling, dynamic load management, and RE-linked charging with corridor-level planning, turning high-power truck charging from a grid constraint into a grid-optimised, commercially scalable solution.

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Company Profile

Smart Freight Centre India

Smart Freight Centre is an international non-profit organization working on Freight Decarbonization to minimize the climate impact of the global freight and logistics sector. Smart Freight Centre has also undertaken a host of Freight Decarbonization initiatives in India under its India program,A working in close collaboration with the India Freight Industry, Policy Offices (national and subnational), Academia & Research and other ecosystem partners, targeting one of the world's largest freight markets with the urgent mission to address the projected 400% increase in CO2 emissions by 2047. Smart Freight Centre, with its India program, is deeply engaged with NITI Aayog's e-FAST India program, collaboratively working with various knowledge partners to advance specific aspects of ZET ecosystem development, while also leading on Freight Emissions Guidance Development and Industry adoption in India. Through these strategic partnerships and a collaborative approach, SFC India envisions and works toward a freight and logistics sector that is sustainable, environmentally responsible, and actively engaged in mitigating climate impact, seeking commitments from logistics service providers and shippers to adopt emission reduction strategies for a more sustainable future.

Author Profile :

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(Chief Executive Officer - Smart Freight Centre)

Christoph Wolff is Chief Executive Officer of Smart Freight Centre, an international non-profit organization focused on reducing greenhouse gas emission from freight transportation.

Until the end of 2021, Christoph was a Member of the Executive Committee for the World Economic Forum, heading the Global Mobility platform that includes the Forum´s initiatives around sustainability and digitization in the supply chain, automotive, aviation and aerospace industry. Before, he was Managing Director of the European Climate Foundation 2014-18, following 16 years at McKinsey as a Senior Partner heading the global travel, logistics and infrastructure practice.

As Board member of DB Schenker, Christoph was responsible for the international growth and operations of the company's rail division. He has been the CEO of companies in the renewable energy sector. A chemical engineer by training from Universities of Aachen and Zurich, Christoph is on the Board of several energy start-ups and Honorary Professor in Energy and Resource Economics at the University of Cologne and Visiting Professor at the HSG St. Gallen, teaching in Mobility and Sustainability.

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Deepali Thakur is a Senior Technical Manager at Smart Freight Centre. With 11 years of experience in Supply Chain industry. Deepali's expertise spans e-mobility, warehouse automation, transportation, supply chain planning, logistics, warehousing, and network design across multiple sectors. In her current role at Smart Freight Centre, she supports global organizations in reducing freight emissions through the adoption of sustainable logistics technologies and practices.

Deepali Thakur
(Senior Technical Manager - Smart Freight Centre)

EV Charging Infrastructure: Market Evolution, Business Opportunities and Structural Constraints

- By Mr. Hirdesh Thakur, Executive Director, EKA Mobility

This paper is organised into six chapters as follows:

- **Chapter 1.** sets the context and presents the central arguments.
- **Chapter 2.** reviews global and national developments in EV charging infrastructure
- **Chapter 3.** examines emerging business opportunities, including the PM E-DRIVE EV PCS scheme.
- **Chapter 4.** outlines systemic challenges hindering large-scale deployment.
- **Chapter 5.** presents policy and industry recommendations.
- **Chapter 6.** applies the Lippitt–Knoster change-management model to the EV charging transition.

CHAPTER-1

Introduction and Executive Summary

To realise the vision of a Viksit, Atmanirbhar Bharat by 2047, India must rapidly transform into a low-cost, low-carbon, globally competitive hub for manufacturing and logistics. Alternative-fuel mobility – especially Made in India electric vehicles and the public charging infrastructure that enables them – will be central to this economic and environmental transition. Given the substantial structural contribution and strong multiplier effects of manufacturing (automotive, electronics) and transportation (freight, passenger, logistics) to India's GDP, this shift has rightly drawn sustained attention from industry stakeholders.

Within this landscape, EV charging infrastructure plays a catalytic dual role. It provides industrial leverage by enabling large-scale domestic manufacturing of EVs, batteries, power electronics, and charging systems. It also provides environmental leverage by reducing tailpipe emissions, lowering diesel consumption, and improving air quality – directly supporting India's commitments toward net-zero by 2070 and nearer-term milestones such as cutting 1 billion tonnes of cumulative carbon emissions and achieving > 30% EV penetration by 2030.

In this context, electric mobility and EV charging infrastructure are not merely facilitators of green transport; they are macroeconomic levers influencing energy security, import substitution, domestic manufacturing, digital infrastructure, and urban development. Accelerating the scale-up of charging infrastructure is therefore essential for India's transition to a net-zero, resilient, and future-ready economy.

This paper summarises key developments, business opportunities, and challenges associated with EV charging infrastructure in India. While the technological principles apply broadly across the EV ecosystem, the primary focus is on public charging infrastructure for electric commercial vehicles (EV CVs)—including both goods carriers (e-freight) and passenger transport (e-buses). This segment is prioritised because, despite constituting only around 5% of the total vehicle fleet, commercial vehicles account for nearly 70% of tailpipe emissions[1] and a significant share of India's crude oil import bill. Moreover, EV CVs face operational complexities – high power demand, rapid turnaround requirements, 24/7 operations, and shared public infrastructure – that are far less prominent in low-powered private charging for e-2Ws, e-3Ws, and personal cars.

Another rationale for this focus is that abundant public-domain research already exists for low-powered small EVs and their charging systems. Recent studies by NITI Aayog, the Department of Science and Technology (DST), and other nodal agencies have examined global technology evolution, manufacturing pathways, financing models, and policy frameworks relevant to LEVs in detail. In contrast, the EV CV segment remains relatively under-analysed despite its large-scale impact and high infrastructural intensity.

Accordingly, this paper adopts a first-principles approach to public EV charging infrastructure through the lens of commercial vehicles, while retaining relevance for all vehicle categories.

India's current public EV charging infrastructure highlights both early progress and the long journey ahead. The country remains in the foundational phase of developing a nationwide charging network. Data reported in the PIB release (PRID 2102783, 13 Feb 2025) show significant gaps between charger installation and energisation by PSU Oil Marketing Companies (OMCs). Under the FAME-II subsidy, OMCs have installed 4,523 EV charging stations but energised only 251 as of 01.01.2025. Additionally, OMCs have deployed 20,035 chargers using their own funds, though energisation and utilisation levels vary widely and are not fully reported. While these numbers reflect only OMCs, they illustrate a broader national gap between policy ambition and operational readiness – particularly for high-power, high-throughput public charging.

This raises a natural question: What should India's baseline public charging infrastructure look like? Global benchmarks suggest one public charger for every 20–40 EVs, depending on charging speed and user behaviour. The IEA Global EV Outlook commonly uses a benchmark

of roughly one public charger per 35 EVs2. India has now surpassed 3.5 million cumulative EV sales (including e-2Ws and e-3Ws), yet its public fast-charging network numbers only in the low thousands3. The gap is even wider for commercial vehicles, which require significantly higher power levels (60 kW–350 kW or more) and near-continuous uptime.

These indicators show that India is still at the earliest stage of its public charging build-out – particularly relative to the infrastructure scale required for commercial vehicle electrification. This early stage also provides an opportunity to design scalable, future-ready solutions.

We believe the scale of this challenge cannot be addressed through linear expansion or isolated incentives. Public charging infrastructure for EV CVs must be reconceptualised as a "time and space" penalty minimisation problem, rather than simply an energy-supply or equipment-deployment task. Here, "time" penalty denotes the period during which a vehicle is unavailable because it is charging, while "space" penalty captures the increased physical real estate demand to accommodate stationary charging in dense commercial and logistics zones.

A central constraint in this transition is the "2× factor," an analytical construct introduced in this paper. It reflects the compounded operational and infrastructure implications of charging electric commercial vehicles (EV CVs). Unlike ICE CVs, which return to service almost immediately after refuelling, EV CVs remain unavailable during charging and may also require thermal or electrical recovery due to stress accumulated during both operation and charging. As a result, operators often need a larger fleet – potentially approaching twice the size of an equivalent ICE fleet in certain use cases – to maintain the same throughput under unchanged duty cycles and route patterns. Range limitations, payload penalties, and mandatory charging windows further intensify this "2× factor" effect.

The implications for prime real estate are equally significant. High-frequency public charging for commercial vehicles requires extensive parking and queuing capacity in areas where urban land is scarce and expensive. Thus, the time and space demands of EV CV charging create infrastructure needs far exceeding what can be solved by simply "installing more chargers."

Viewed through this lens, conventional approaches – such as isolated subsidies, limited pilots, or equipment-led planning – are insufficient. Meeting nationwide EV CV charging needs requires coordinated, system-level action integrating policy reform, technological innovation, operational redesign, land-use planning, and manufacturing readiness. This complexity, however, also signals enormous industrial and commercial opportunities for manufacturers, operators, financiers, EPC providers, software innovators, and infrastructure developers.

At a deeper analytical level, the time dimension shows that charging duration directly affects vehicle utilisation and revenue potential. High-power charging can reduce downtime but introduces thermal and electrical constraints that influence reliability and turnaround. The space dimension shows the land intensity of charging: vehicles are stationary for the entire charging period, and high-power systems (150–350 kW and above) demand either strong grid capacity or large battery-buffer systems. Depot-only

charging models are insufficient for high-utilisation routes, making public charging nodes indispensable – but suitable land is increasingly difficult to secure.

When these time, space, and fleet-size requirements interact, a compounding multiplier effect emerges. This distinguishes public EV CV charging from low-powered private charging ecosystems, which face far fewer concurrency, power-density, and land constraints. Addressing these challenges requires integrated planning across grid infrastructure, land-use regulation, power electronics manufacturing, digital systems, financing models, utilisation guarantees, safety norms, and regulatory mechanisms. This paper uses the integrated 2× systems perspective as its foundational analytical framework.

Despite the constraints, public EV charging remains one of India's most promising emerging industrial and infrastructure domains. Opportunities span high-power charger manufacturing, EPC deployment, fleet-level energy optimisation, charging-as-a-service platforms, solar-hybrid and battery-buffer systems, payments and fleet-scheduling software, switchgear and thermal-management supply chains, and a growing set of PPP models. Large-scale deployment under the PM E-DRIVE mission is particularly well-positioned to catalyse industrial growth. India can now leapfrog into next-generation charging architectures, including megawatt-scale truck charging, pantograph-based bus systems, freight-fleet battery swapping, depot–grid optimisation, solar-integrated public charging, and interoperable smart-charging platforms.

Realising these opportunities at scale requires moving beyond fragmented, supply/demand side incentives led initiatives. The transition demands a systemic policy redesign that treats public charging as essential national infrastructure for economic productivity, energy security, and long-term decarbonisation. This shift requires a stable/predictable end-to-end policy architecture that ecosystem players can execute upon; synchronisation across vehicle, charger, and grid ecosystems; manufacturing readiness; clear land-use and zoning norms; scalable financing mechanisms; performance-linked regulation; robust safety standards; and digital interoperability. Only such an integrated, ambitious policy posture can align India's charging infrastructure trajectory with the magnitude of its commercial vehicle electrification goals.

CHAPTER-2

Developments in EV Charging Infrastructure: Global Evolution, India's Trajectory, and Emerging Technical Paradigms

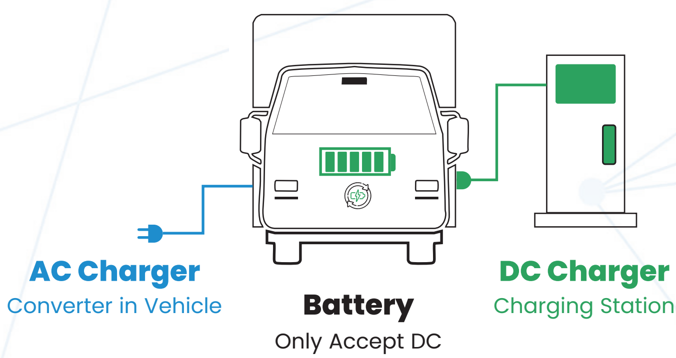
The development of electric vehicle (EV) charging infrastructure over the past decade reflects a global transition from experimentation to industrial-scale deployment. While regions such as the United States, Europe, and China each followed distinct institutional and technological paths, their progression converges on a common recognition: charging infrastructure must evolve in parallel with vehicle technology, grid readiness, mobility patterns, and industrial capabilities. India's trajectory, though compressed in time, is shaped by unique constraints and opportunities—particularly the dominance of two- and three-wheelers, the late but rapid emergence of commercial EVs, and structural challenges across land, electricity distribution, and urban logistics.

This chapter provides a comprehensive overview of these developments, synthesising insights from international experience, industry evolution, India's policy landscape, and authoritative documents such as the DST's R&D Roadmap Volume 3: Technologies to Overcome Hindrances to E-Mobility and the Transforming Trucking in India study by ZET. The aim is to establish a foundational understanding of the

technological, infrastructural, and operational paradigms that shape EV charging infrastructure globally and in India, with particular attention to the commercial vehicle (CV) segment.

2.1 Global Evolution: From Low-Power AC to High-Power DC and Megawatt-Class Systems

The global development of EV charging has unfolded in three broad phases, each defined by technological maturation, vehicle capability, and policy support.



The first phase, beginning around 2010, was dominated by low-power AC charging. Early adoption in countries such as the United States and Norway relied heavily on home and workplace charging at power levels of 3–7 kW. Public charging existed but furnished limited power and inconsistent availability. This infrastructure model was adequate for the earliest generation of passenger EVs but entirely inadequate for commercial applications, which require high utilisation rates and rapid turnaround times.

The second phase, starting around 2016, saw the proliferation of DC fast charging. Networks such as Tesla's Supercharger system in the U.S. and Europe, Electrify America, IONITY, and China's State Grid installations enabled charging at 50–150 kW. This phase marked a transformative moment: EVs could now undertake intercity travel, and commercial vans and buses began to adopt electrification. The development of standardised connectors, robust power electronics, and liquid-cooled cable systems accelerated this shift.

The third and current phase is characterised by industrialised deployment of high-power charging (HPC), typically in the 150–350 kW range, and the emergence of megawatt-class charging systems (MCS) for heavy-duty vehicles. This phase corresponds with the growth of long-range EVs, the electrification of heavy trucks in China, Europe, and select U.S. states, and significant investment in grid reinforcement, energy storage, and power-to-mobility integration. MCS pilots now operate at 750 kW–1.2 MW, enabling heavy-duty vehicles to recharge rapidly during mandatory driver rest breaks.

These global developments establish a template for technological progression that India is now entering—albeit under distinct infrastructural constraints.

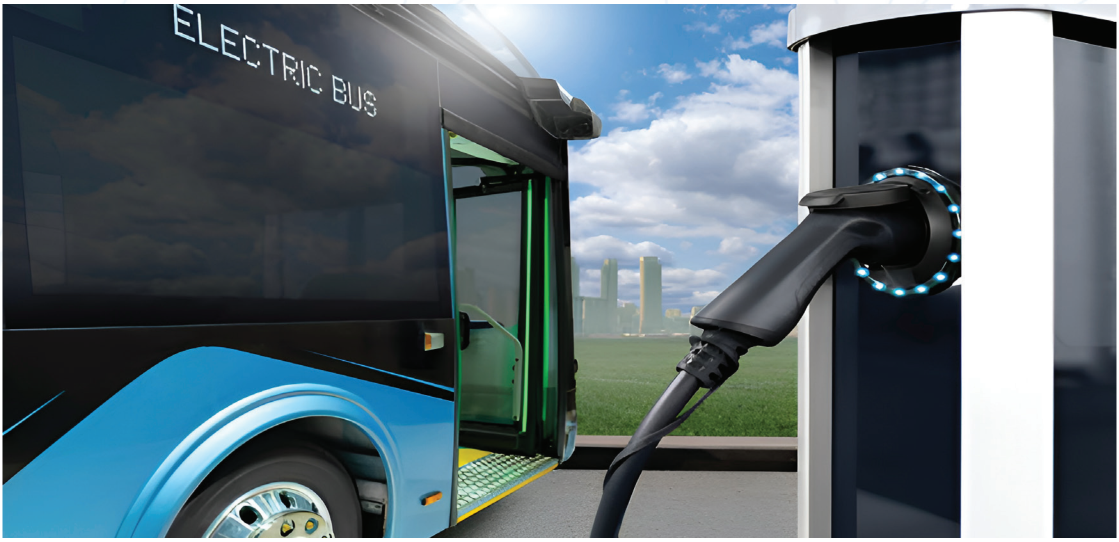
2.2 Taxonomy of Charging Technologies: A Progressive Spectrum of Power and Use Cases

EV charging technologies can be understood along a spectrum of increasing power and complexity, each corresponding to specific vehicle types and operational profiles. This taxonomy helps clarify why commercial vehicle electrification imposes very different infrastructure demands compared to smaller personal EVs.

At the lower end of the spectrum lies AC charging, ranging from 3.3 kW to 22 kW. AC charging is widely deployed for two-wheelers, three-wheelers, and passenger cars, especially in home or workplace settings. Its low cost and minimal grid requirements make it accessible, yet its slow charging times render it unsuitable for commercial vehicles with tight duty cycles. DST's R&D roadmap emphasises that AC charging cannot meet the operational needs of high-utilisation fleets requiring turnaround within one to two hours.

DC fast charging occupies the midrange of this taxonomy. Typically operating between 30 and 150 kW, it supports passenger cars, light commercial vehicles, and smaller buses. Charging times are significantly reduced, often falling within the 30–60-minute window. The ZET report identifies the 60–120 kW range as the "practical sweet spot" for light commercial vehicles in India, balancing energy transfer needs with manageable grid upgrades.

High-power charging infrastructure (150–350 kW) is increasingly necessary for medium-duty trucks, intercity buses, and high-utilisation commercial vans. This category demands substantial grid support, power electronics sophistication, and efficient thermal management.



Beyond these lies the megawatt-class category, still in pilot stages globally. MCS solutions are essential for long-haul trucking and heavy commercial transport, where batteries must replenish hundreds of kilowatt-hours within short rest windows. Countries such as Germany, the U.S., and China have advanced MCS pilot projects, reflecting their prioritisation of freight decarbonisation. India has no commercial MCS deployments yet, but alignment with this global direction is crucial for long-term competitiveness.

2.3 Alternative Charging Methods: Pantographs, Battery Swapping, and Hybrid Systems

While plug-in charging dominates global discourse, alternative charging methods have emerged for specialised use cases.

Pantograph charging, widely adopted in Europe and increasingly in Chinese and Indian cities, enables automated high-power charging for buses through overhead connectors. This method allows “opportunity charging” at bus terminals or enroute stops, ensuring fleet reliability without requiring large onboard batteries. Possible Indian deployments in Indian cities e.g., Nagpur pilot4 demonstrate its growing relevance.

Battery swapping has achieved global traction primarily in the two- and three-wheeler segments, with notable success in India. Standardised battery packs enable rapid turnaround, making swapping viable for last-mile delivery fleets. However, DST identifies technical hurdles related to battery standardisation, BMS interoperability, warranty frameworks, and ownership models, which restrict swapping’s applicability to heavier vehicles.

Hybrid charging systems combining power from the grid with battery storage are gaining prominence, especially in regions where grid constraints inhibit high-power deployment. These systems lower demand peaks, support intermittent renewable energy integration, and enhance resilience—qualities essential for India’s future commercial EV hubs.

2.4 International Approaches to Commercial EV Charging Infrastructure

Commercial vehicle charging infrastructure has evolved uniquely across different regions, shaped by regulatory structures, freight patterns, and industrial priorities.

In the United States, electrification is driven by a combination of federal programs (e.g., NEVI) and state-level mandates, particularly in California. Depot charging remains dominant for fleet operations, supported by utility programs and time-of-use tariffs. Public high-power charging hubs near ports, logistics corridors, and distribution centres are expanding, reflecting the need for heavy-duty electrification.

Europe adopts a more standardised and centrally coordinated approach, supported by municipal planning and regulations requiring cities to provide charging infrastructure.

Pantographs for buses, high-power hubs along highways, and stringent emissions zones collectively push both passenger and freight electrification. The EU's Alternative Fuels Infrastructure Regulation (AFIR) mandates minimum HPC coverage along Trans-European Transport Network (TEN-T) corridors.

China exemplifies the highest level of state-led coordination, with State Grid and Southern Grid driving massive deployment of DC fast chargers and freight-focused charging hubs. Standardisation is extensive, enabling interoperability and economies of scale. At ports and industrial hubs, China has begun deploying megawatt-scale chargers and battery-swapping systems for heavy trucks, reflecting integrated planning between energy and transport sectors.

2.5 India's Charging Infrastructure Trajectory: A Compressed and Complex Evolution

India's development path differs markedly from the global experience due to its unique vehicle mix, cost sensitivities, infrastructural constraints, and policy evolution. The country's EV transition has occurred in three compressed phases.

The first phase, roughly until 2020, was dominated by AC charging for two-wheelers, three-wheelers, and early passenger EVs. Public charging was sparse, standards were fragmented, and commercial EVs were nearly absent. The primary barrier was cost, as well as insufficient charging reliability.

The second phase, between 2020 and 2023, saw accelerated deployment of DC fast chargers—driven by private operators such as Tata Power, ChargeZone, Jio-BP, Statiq—and initial investments by public sector entities. Energy utilities and oil marketing companies (OMCs) began installing chargers, although energisation delays and low utilisation prevented full operationalisation. Bus electrification under FAME-II contributed to the development of depot charging, which remains one of India's most reliable charging environments.

The third and current phase (2023 onward) is characterised by systemic planning efforts through PM E-DRIVE, a shift toward cluster-based PCS deployment, and the early emergence of high-power charging hubs for commercial vehicles. Digital integration, interoperability, and operational reliability are receiving more attention. India's charging ecosystem is thus transitioning from an installation-driven model to an availability-driven, utilisation-driven, and standards-driven architecture.

2.6 Technical Insights from the DST R&D Roadmap: Power Electronics, Thermal Management, and Grid Integration

DST's R&D Roadmap Volume 3 provides a rigorous assessment of the technological gaps that must be addressed for scalable charging infrastructure. It identifies three overriding challenges.

First, power electronics remain heavily import-dependent, particularly high-power modules, conversion systems, and thermal management components. Domestic development of high-efficiency converters, SiC-based power electronics, and liquid-cooled cable systems is essential for reducing costs and enhancing reliability.

Second, thermal management poses a major engineering challenge. High-power charging induces substantial heat loads both within chargers and vehicle batteries. Without advanced cooling strategies, high charging rates cannot be sustained, particularly in India's climatic conditions. DST notes that indigenous R&D in thermal systems is critical for future MCS adoption.

Third, grid integration challenges affect reliability. DST emphasises the need for smart charging systems, load management algorithms, vehicle-grid coordination, and hybrid energy systems incorporating battery storage and renewables. These recommendations align closely with the infrastructural constraints described in later chapters.

2.7 Insights from "Transforming Trucking in India":

The ZET report offers a detailed examination of India's freight electrification landscape and identifies charging as the central bottleneck. It underscores that light commercial vehicles can electrify relatively quickly under 60–120 kW charging environments, whereas medium and heavy trucks require high-power hubs with 200–600 kW capability—far beyond India's current mainstream deployments.

The report stresses that grid constraints are profound at logistics hubs, transport nagars, and agricultural markets (APMCs). It also highlights that freight operations are spatially concentrated and predictable, making them ideal candidates for planned charging hubs—provided land and grid access can be coordinated. These insights support the original systems-thinking and prioritisation frameworks proposed in Chapter 1.

2.8 Synthesis: Implications for India's Commercial EV Charging Future

The global and national developments summarised above illustrate the increasingly complex architecture of EV charging. For India, the implications are clear. First, the evolution from low-power AC to high-power DC and eventually megawatt-class charging is not optional but necessary for commercial vehicle adoption. Second, infrastructure planning must follow a systems-thinking approach, integrating land availability, grid readiness, fleet operations, and manufacturing capacity. Third, India's charging ecosystem must prioritise use cases where structural conditions already enable high success rates—ports, point-to-point logistics, industrial parks, and controlled shuttle operations—before scaling to long-haul corridors.

Finally, the technological pathways highlighted in DST's roadmap and the operational insights from ZET's study demonstrate that India must build indigenous capabilities in power electronics, thermal management, and energy integration to ensure long-term resilience.

This chapter thus provides the technological and developmental foundation for evaluating business opportunities (Chapter 3), diagnosing systemic roadblocks (Chapter 4), and framing comprehensive national recommendations (Chapter 5).

CHAPTER-3

Business Opportunities in India's EV Charging Infrastructure Ecosystem

The expansion of EV charging infrastructure represents one of the most significant industrial opportunities of the next two decades for India. As the country transitions toward electrified mobility—driven by national commitments on climate, energy security, and manufacturing competitiveness—the demand for accessible, reliable, and high-power charging systems is set to grow exponentially. The opportunity spans multiple technological layers, from power electronics and energy management systems to public charging networks, digital platforms, and innovative financing models. This chapter examines these opportunities through the lens of emerging policy frameworks—particularly the PM E-DRIVE EV Public Charging Stations (PCS) Operational Guidelines—and evolving private-sector initiatives such as the Tata Power individual-owned charger scheme. It situates these developments within the broader market architecture and highlights how India can translate regulatory impetus into large-scale industrial and commercial value creation.

3.1 Policy as a Catalyst: The PM E-DRIVE EV PCS Operational Guidelines

The PM E-DRIVE scheme, launched by the Ministry of Heavy Industries (MHI), is the most ambitious and structured national effort yet to accelerate the deployment of public charging infrastructure. The Operational Guidelines for Public Charging Stations (PCS) published under this scheme represent a marked shift from earlier subsidy-driven approaches by adopting a coordinated, standards-based, and cluster-oriented strategy. In this sense, PM E-DRIVE attempts to move India from fragmented installations—often characterised by non-operational chargers, inconsistent power availability, and weak utilisation—to a systematic network of functioning PCS.

The guidelines first identify a broad and inclusive set of eligible entities, ranging from central and state government agencies and public sector undertakings (PSUs) to authorised nodal agencies and urban local bodies. These entities are responsible for aggregating demand for charging stations and submitting consolidated proposals through an online portal. This approach mirrors international models in which government authorities act as intermediaries to ensure uniform coverage and equitable distribution—similar to the municipal-driven deployment seen in European cities and the state-led role in China's State Grid and Southern Grid.

At the core of the PM E-DRIVE guidelines is a focus on viability, interoperability, and operational certainty. Subsidies are disbursed in tranches, with the final instalment released only after the charging station is commissioned, energised, and digitally onboarded onto the National Unified EV Hub. This conditional mechanism directly addresses a historical weakness in India: the discrepancy between chargers

that are physically installed and those actually operational, a gap highlighted earlier with reference to the OMC data from the 2025 PIB release. By linking incentives to operational status and telemetry compliance, PM E-DRIVE aligns private incentives with public performance metrics.

Another significant commercial opportunity arises from the categorisation of different types of PCS under the scheme. PM E-DRIVE allows proposals for a wide range of site typologies, including commercial centres, office complexes, industrial clusters, highway corridors, bus terminals, and freight hubs. This classification implicitly acknowledges the heterogeneous requirements of different vehicle segments and opens the market for site-specific charging solutions. For commercial vehicles, especially those operating in logistics, urban freight, and intercity bus networks, this flexibility enables tailored infrastructure designs—ranging from 60–120 kW chargers for light commercial vehicles to 150–350 kW high-power chargers for larger fleets.

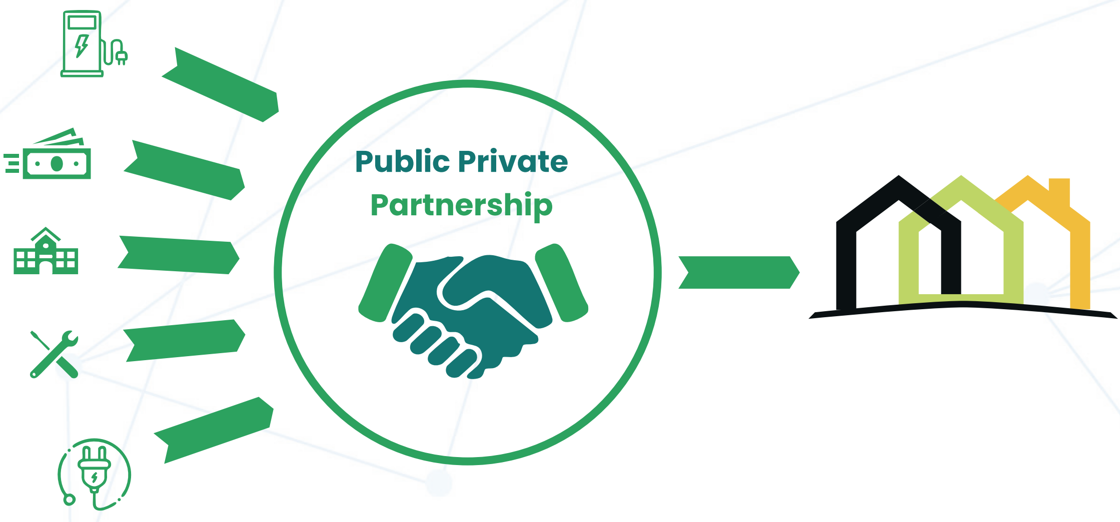
The guidelines also incentivise the deployment of renewable energy-enabled PCS, battery-buffered systems, and charging stations designed to serve multiple vehicle categories. These technological directions reflect the recommendations in the DST R&D Roadmap, which highlight the need for indigenous high-power chargers, thermal management innovations, and solutions to mitigate grid constraints. The combination of strategic subsidy deployment and technology-agnostic design principles positions PM E-DRIVE5 not just as a financing scheme but as a long-term market-shaping instrument.

3.2 Public-Private Partnerships and Market Structuring

India's EV charging market is entering a phase similar to what the renewable energy market experienced a decade ago: a shift from policy experimentation to consolidation, scale, and the emergence of diversified operators. The opportunities created by PM E-DRIVE amplify this trend by enabling new forms of public-private partnerships (PPPs). For instance, urban local bodies may provide land, while private operators install, operate, and maintain chargers under revenue-share or licence-fee models. Such arrangements are particularly suited to land-constrained cities where high-value commercial real estate can be monetised for charging stations.

Another structural opportunity lies in the integration of charging networks with digital mobility platforms. The guidelines require PCS to transmit live data on availability, pricing, power rating, and utilisation to the National Unified Hub. This aligns India with global practices where real-time data platforms facilitate efficient charger utilisation, route planning, and grid coordination. For private operators, interoperability and data-sharing frameworks create a secondary layer of commercial possibilities: application programming interfaces (APIs), analytics-driven demand forecasting, pricing engines, and fleet optimisation services.

The emergence of roaming agreements between charge-point operators (CPOs)—similar to the European roaming model—is another commercial frontier. As more PCS become digitally integrated, there is an opportunity for multi-operator subscription models, loyalty plans, bundled fleet energy contracts, and unified payment mechanisms. CPOs that invest early in building interoperable platforms will have a strategic advantage in this interconnected market.



3.3 The Tata Power Individual-Owned Chargers Model

While PM E-DRIVE focuses on large-scale, public deployments, Tata Power's (and many others) initiative allowing individuals and small businesses to own and operate EV chargers introduces a decentralised and entrepreneurial model. Under this programme, individuals can purchase and install DC fast chargers at suitable locations (typically commercial or high-traffic areas) and earn revenue through charging transactions processed by Tata Power's EZ Charge platform.

This scheme democratises the business of charging infrastructure by lowering entry barriers and distributing ownership across a wider base. For India's sprawling geography—ranging from small towns to industrial belts—this distributed model is particularly relevant. It mirrors global innovations such as Norway's privately operated destination chargers and the community-owned chargers seen in parts of the U.S. and Europe.

The programme also illustrates a shift toward a platformised charging economy, where hardware ownership can be decoupled from operational management. Tata Power handles software integration, payments, maintenance, and customer support, while the owner provides the site and capital investment. This model allows for scalability in locations where government-led PCS deployment may be slow, and it creates micro-entrepreneurial opportunities, especially in Tier-2 and Tier-3 regions.

Moreover, as EV CV charging grows in demand, the Tata Power model could evolve into fleet partnerships: small logistics operators installing chargers at warehouses, transport nagars, and freight aggregation points, monetising both public charging and dedicated fleet charging contracts. Given the constraints identified in earlier chapters—particularly the "time and space" problem—private decentralised installations can relieve pressure on public PCS by absorbing part of the fleet-charging demand.

3.4 Business Opportunities Across the EV Charging Value Chain

The charging ecosystem is not a monolithic industry but a constellation of interconnected sectors. The PM E-DRIVE framework, combined with private-sector innovation, expands opportunities in several key domains.

1. EPC and Infrastructure Deployment Services

Engineering, procurement, and construction (EPC) firms stand to gain from large-scale charger installations. These firms are critical not only for the installation of chargers but also for associated infrastructure such as transformers, cabling, substations, civil works, and safety systems. The frequency of DISCOM delays and grid-quality issues indicates that firms capable of providing integrated power solutions—especially those incorporating hybrid solar, energy storage, and load management—will find sustained demand.

2. High-Power Charger Manufacturing and Assembly

Demand for 60–350 kW chargers are set to grow dramatically over the next decade, especially as commercial EV adoption increases. The DST roadmap identifies domestic manufacturing of power electronics as a national priority; this creates a significant opportunity for Indian firms to localise high-power chargers, thermal systems, and cooling modules.

3. Battery Buffer and Energy Storage Solutions

Battery-buffered charging is a pivotal business opportunity. It enables fast charging where grid capacity is limited and improves charging economics by enabling time-of-day arbitrage. Firms specialising in lithium-ion and LFP storage systems, hybrid renewable systems, and compact power modules can vertically integrate their solutions with PCS deployments.

4. Software, Telemetry, and Energy Management

Digital architecture underpins the viability of public charging. Opportunities include:

- Charger management systems (CMS),
- OCPP-compliant backends,
- Energy optimisation algorithms,
- Fleet energy dashboards,
- Payments and billing software, and
- Predictive maintenance tools.

Companies capable of integrating these systems with the National Unified Hub will occupy crucial positions in the data layer of the EV ecosystem.

5. Financing and Business Models

Charging infrastructure is capital intensive and traditionally slow to monetise. This creates opportunities for asset financing, leasing models, and infrastructure-focused investment vehicles. Green bonds, blended finance, and credit-enhanced energy models can reduce the cost of capital, particularly for high-power hubs serving commercial EVs. Charging-as-a-Service (CaaS) and Energy-as-a-Service (EaaS) offerings will become central for commercial fleets seeking predictable operating costs.

3.5 The Commercial Vehicle Opportunity: India's Biggest Growth Engine

The electrification of commercial vehicles presents the most substantial long-term opportunity for the charging sector. As Chapter 1 discussed, although commercial vehicles form a small portion of India's vehicle stock, they contribute disproportionately to emissions and fuel consumption. The combination of high utilisation, predictable routes, and concentrated fleet ownership makes them suitable candidates for structured charging infrastructure.

The business case for EV CV charging infrastructure is strengthened by several factors. First, the energy consumption per vehicle is high, leading to substantial and predictable charging demand. Second, commercial EVs generally charge on a schedule that can be optimised around depot operations, shift timings, and freight schedules. Third, fleet operators value uptime and predictability, making them ideal customers for long-term charging contracts, thereby enabling revenue certainty for PCS operators.

Moreover, the emergence of electrified freight corridors represents a unique opportunity for India to leapfrog into high-power, grid-integrated infrastructure that serves both logistics and passenger transit. These corridors will require hybrid models combining depot charging, enroute charging, pantograph systems for buses, and eventually megawatt-class chargers for long-haul trucks. Companies capable of offering corridor-wide services, integrating distributed energy resources, and coordinating with DISCOMs will likely dominate this emergent market.

3.6 Renewable-Powered Charging and the Role of Decentralised Energy

The economics of EV charging are tightly linked to electricity tariffs, demand charges, and energy procurement models. One of the most promising business opportunities lies in renewable-powered charging: solar-plus-storage systems for small and medium PCS. These systems reduce dependence on grid upgrades, lower operating costs, and improve reliability in areas with inconsistent power supply. EKA Mobility's work on developing solar-powered chargers that can bring operating costs for smaller commercial EVs close to zero exemplifies this innovation frontier.

Renewable charging also aligns with ESG mandates and can attract green financing, which increasingly favours infrastructure with demonstrable environmental impact. As the government pushes for net-zero pathways, PCS equipped with renewable energy assets may receive preferential regulatory treatment, expedited permissions, or additional incentives.

3.7 Convergence of Data, Energy, and Mobility: A Platform Opportunity

The rapid digitalisation of charging networks creates opportunities for integrated energy-mobility platforms. These platforms can combine telematics, demand forecasting, vehicle diagnostics, route optimisation, charger availability, and dynamic pricing into one unified interface. They can also aggregate distributed chargers, enabling virtual charging networks that allow operators to diversify their fleet-charging options across geographies.

India's National Unified EV Hub, once fully implemented, provides the data backbone necessary for such platforms. Companies that integrate deeply with this hub can develop value-added services such as subscription-based charging, fleet energy contracts, and predictive grid support. The monetisation potential of these platforms lies not only in transaction fees but in analytics, operational optimisation, and energy management.

3.8 Summary

The business opportunities in India's EV charging infrastructure are multi-layered and deeply interconnected. The PM E-DRIVE PCS Operational Guidelines establish a national framework that links financial incentives with operational performance, while private-sector initiatives such as the Tata Power individual-ownership model democratise participation in the charging economy. The market for high-power charging—especially for commercial vehicles—is poised to expand rapidly, supported by advances in power electronics, battery storage, and digital technologies. As India builds toward its 2030 and 2047 climate and economic goals, charging infrastructure will evolve into a foundational utility sector, blending energy systems, digital services, and mobility operations in ways that create sustained industrial and commercial growth.

CHAPTER-4

Roadblocks in Developing EV Charging Infrastructure in India

The evolution of EV charging infrastructure in India is occurring at a moment when the country is simultaneously expanding mobility demand, rationalising energy consumption, and transitioning to a low-carbon economy. The opportunities described in the preceding chapter are undeniable yet realising them at scale requires resolving a complex mix of structural, technical, economic, regulatory, and behavioural challenges. These roadblocks are particularly acute for commercial vehicles (CVs), whose operational profiles, energy requirements, and spatial demands differ fundamentally from those of smaller electric vehicles. Insights from the DST R&D Roadmap on "Technologies to Overcome Hindrances to E-Mobility" and the "Transforming Trucking in India" study show that the barriers are multi-tiered, interdependent, and embedded across the energy, mobility, land-use, and financial systems.

This chapter synthesises the core challenges into a coherent analysis. It examines the reasons behind India's slow energisation rates, the recurrent delays in grid readiness, the difficulty of allocating real estate for charging hubs, the technological barriers in deploying high-power chargers, and the economic frictions that hamper long-term investment. It also examines why CV charging infrastructure is inherently more complex than passenger EV infrastructure, and why India must adopt a systemic approach to address these constraints.

4.1 The Installed vs. Energised Paradox: A Symptom of Systemic Mismatch

India's persistent gap between installed chargers and operational (energised) chargers is perhaps the most visible symptom of deeper infrastructural and governance challenges. The 2025 PIB note, which documented the discrepancy between thousands of chargers "installed" and only a few hundred actually energised at OMC retail outlets, reveals a systemic misalignment between charger deployment and grid provisioning. The causes are both institutional and technical.

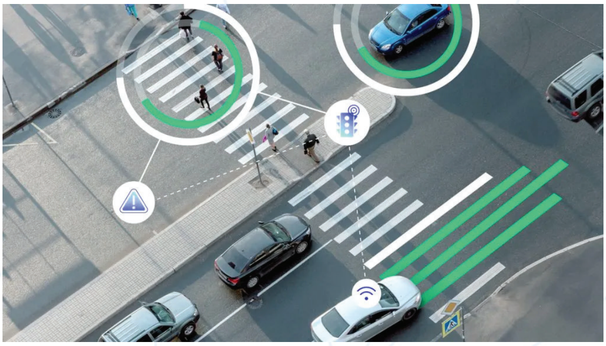
The first barrier arises from the legacy processes governing electricity distribution companies (DISCOMs). Many DISCOMs remain financially constrained, risk-averse, and slow to respond to new high-load demands. Charging stations—especially DC fast chargers and high-power chargers—require dedicated feeders, transformer upgrades, or even new substations. These upgrades demand capital expenditure and long approval cycles. Consequently, operators often install the hardware first, expecting the grid connection to follow, only to find that the utility timelines do not match project timelines.

This mismatch is further accentuated by the lack of synchronised planning. Charger installation is executed by operators, oil marketing companies, or private developers, whereas grid enhancement is the responsibility of DISCOMs. Without integrated planning mechanisms and advanced load forecasting, the two systems evolve asynchronously. In many cases, the grid is simply not ready for fast charging loads.

The DST R&D Roadmap identifies this as a fundamental structural challenge: the absence of coordinated planning between the power and mobility sectors. It notes that high-power DC charging requires not merely extra feeders, but systematic forecasting of future EV load, a function that is not yet institutionalised in most states. The roadmap further argues that without intelligent load management and distributed energy resources—particularly battery storage—the grid will struggle to support fast charging growth.

In essence, the installed vs energised paradox is not merely a logistical delay; it is evidence of a systemic inability to align infrastructure timelines across different sectors. Unless this alignment is structurally embedded through regulatory reforms, the paradox will persist even as chargers proliferate.

4.2 The "Time and Space × 2x Utilisation Factor" Challenge for Commercial Vehicles



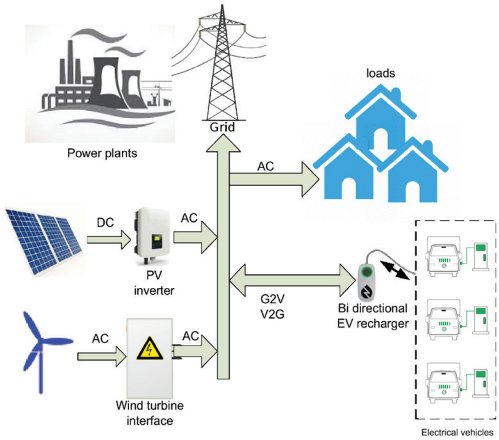
As emphasised in the Introduction, public charging infrastructure for commercial EVs is fundamentally a "time and space" problem. The difficulty arises from the fact that, unlike ICE vehicles, EVs consume time not only during operations but also during charging. The "2x factor" stems from an empirical operational reality: to move the same quantity of freight or passengers, EV fleets may require roughly twice the number of vehicles if charging downtime is not meticulously optimised. This magnifies the demand for land, charger availability, and operational coordination.

For heavy commercial vehicles, the challenge is even more severe because charging events are longer and energy requirements are higher. A typical electric truck or intercity bus requires anywhere between 150 and 600 kWh per charging cycle. Even at high-power charging rates of 150–350 kW, charging times remain substantial, especially in crowded hubs. As the ZET study notes, even light commercial vehicles, though more flexible, impose significant space and scheduling demands at depots and hubs.

The spatial challenge is compounded by India's urban form. Transport nagars, logistics parks, mandis, and freight aggregation points are often congested, unplanned, and located in peri-urban zones with limited scope for expansion. High-power charging hubs need clear circulation space, queuing lanes, and adequate vehicular turning radius, all of which are scarce in built-up areas.

This scarcity intensifies the operational burden: if an EV is occupying prime real estate for charging, that space is unavailable for other operational functions such as loading, unloading, or parking. Thus, the "2x factor" translates into exponential pressure on real estate. What appears as a simple charging event becomes a spatial bottleneck that reverberates across operational logistics. Designing charging hubs without addressing these spatial-logistical intersections will result in high congestion, underutilised chargers, and financially unviable PCS.

4.3 Grid Limitations: Technical Barriers in Power Delivery and Quality



India's electricity distribution system was not originally designed to accommodate high-intensity, distributed fast-charging loads. Across states, grid capacity varies significantly, and even within cities, transformer loading, feeder strength, and supply reliability are inconsistent. For the EV charging industry, these inconsistencies manifest as some of the most immediate roadblocks.

High-power chargers, particularly those above 60 kW, demand stable three-phase power, high short-circuit ratings, and low-voltage fluctuations. However, many distribution networks in India suffer from voltage drops, especially during peak evening hours. Fast chargers operating under such conditions face risks of derating, shutdowns, and even equipment damage.

The DST Roadmap highlights the engineering challenges: power electronics are sensitive to fluctuations, and fast chargers require advanced thermal management systems to maintain performance under variable supply.

Additionally, many fast-charging installations need separate transformers because the existing distribution transformer capacities—often 200–400 kVA—are insufficient to support multiple high-power chargers operating simultaneously.

For commercial EV charging, the requirement is even more demanding. Heavy-duty charging hubs may require 2–5 MVA of dedicated power. Many freight locations do not have such capacity within reasonable distance. Even where technical feasibility exists, transformer procurement, right-of-way clearances for cabling, and substation augmentation take months or years.

Without widespread adoption of energy storage systems to buffer peak loads, the grid will remain a bottleneck. India has made early moves in this direction, but storage economics still remain challenging for private operators unless supported by regulatory measures.

4.4 Regulatory Fragmentation and Multi-Agency Coordination Challenges

EV charging infrastructure touches multiple jurisdictions simultaneously: urban development authorities, electricity regulators, municipal bodies, state transport departments, highway authorities, and private land-owners. This multiplicity of actors creates procedural friction, especially in high-value locations.

Permits for land-use conversion, electrical load sanctioning, fire safety compliance, environmental approvals, and rights-of-way follow separate processes. In many cities, the approvals needed for a single PCS can involve engagements with more than five government bodies. The absence of unified permissions creates unpredictable timelines and significantly raises project risk.

The PM E-DRIVE Operational Guidelines attempt to address this by mandating designated nodal agencies in each state. However, the success of this model depends heavily on the willingness of state-level agencies to streamline internal processes. In contrast, countries like China benefit from vertically integrated power utilities and strong central coordination, while Europe benefits from harmonised standards and municipal-led planning frameworks.

Regulatory ambiguity also emerges in charger classification. Charging stations simultaneously operate as commercial electricity consumers, public utilities, and transport infrastructure nodes. Tariff structures for commercial electricity users—especially demand charges—can be prohibitive for charging operators, particularly during low-utilisation phases. The lack of a national tariff framework for EV charging creates uncertainty and disincentivises investment in states with high industrial tariffs.

4.5 High-Power Charging: Technological, Thermal, and Engineering Barriers

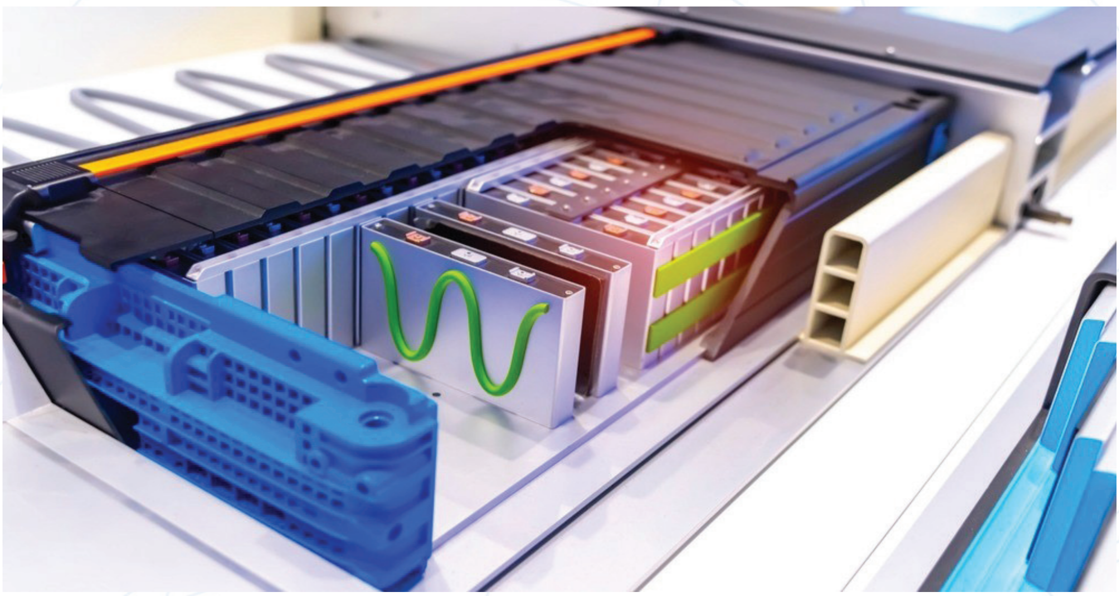
The deployment of high-power charging (150–350 kW and above) introduces engineering complexities that go well beyond conventional EV infrastructure. Chargers of this class require robust power electronics, sophisticated cooling modules, precise thermal management, and hardened electrical components. The DST Roadmap emphasises that indigenous development of these technologies remains at an early stage; India still relies heavily on imported power modules, IGBT-based converters, liquid cooling systems, and specialised connectors.

For commercial vehicles, the requirements escalate further. High-power charging generates substantial heat not only within the charger but also in the vehicle battery. This necessitates integrated thermal management strategies across vehicle and charger systems. Without adequate cooling, charging speeds must be throttled to prevent thermal runaway risks. Heavy-duty commercial vehicles, which require multiple high-power charging events per day, are particularly exposed to these constraints.

There is also the related issue of harmonising charging standards. India currently supports multiple standards (CCS2, GB/T, Bharat DC), and while CCS2 dominance is expected for cars and LCVs, the standards for heavy trucks—particularly MCS—are still evolving globally. Without early adoption of a harmonised national standard for high-power CV charging, India risks fragmentation similar to the early years of telecom infrastructure.

4.6 Land and Real-Estate Constraints: The Spatial Economics of Charging

Land availability is perhaps the most underappreciated yet decisive barrier for EV charging.



Charging stations require accessible, well-located plots that facilitate vehicle ingress, egress, queuing, and parking. For heavy commercial vehicles, the space required increases dramatically: a single truck bay can require 150–300 square metres, depending on turning radii and circulation patterns.

Urban freight hubs, transport nagars, and logistics clusters in India rarely have surplus land. Many have grown organically, lacking structured layouts or expansion potential. Establishing high-power hubs in such environments is not merely a matter of installing equipment; it involves reconfiguring existing land use, relocating activities, or investing in vertical or multi-level charging solutions, which are significantly more expensive.

On highways, land acquisition is equally challenging. Public charging requires land with frontage, accessibility, and visibility—characteristics that also make such land expensive.

Without a national-level land-bank policy for EV charging—similar to the land allocations given historically to petrol pumps—scaling PCS, especially for CVs, will be slow and inconsistent.

4.7 Economic and Financing Barriers: The Viability Gap in PCS Operations

The economic viability of charging stations depends on three interlocking variables: capital expenditure, utilisation rates, and electricity tariffs. For most PCS operators in India, these variables are currently unfavourable. Capital costs for fast-charging equipment remain high because of import dependence and limited domestic manufacturing. Civil and electrical works add significantly to the initial costs—particularly when dedicated transformers or substations are needed.

Utilisation rates remain low in most public charging locations. India's EV stock is still dominated by 2W and 3W vehicles, which rely on home or private charging. Public chargers for cars and LCVs see sporadic utilisation except in a few metropolitan hotspots. For heavy commercial vehicles, the fleet is still nascent, so utilisation at high-power hubs will take years to ramp up. This low utilisation creates a long payback period.

Electricity tariffs further affect revenue potential. Many states impose high demand charges on commercial consumers. Fast-charging operators must pay for peak demand even if chargers are underutilised. Tariff uncertainty also creates risk: the absence of national tariff guidelines means that operators face variable electricity costs across states.

Private capital, therefore, remains cautious about large-scale investments without assurances of utilisation or tariff rationalisation. Financial innovation—such as infrastructure-backed EV funds, green bonds, fleet-charging contracts, and risk-sharing models—is still in early stages.

4.8 Digitalisation, Interoperability, and Data Governance Challenges

While India is moving toward digital integration through the National Unified EV Hub, several challenges remain. Operators vary widely in the quality of their telematics systems, charger management software, and OCPP implementation. Many chargers are technically OCPP-compliant but fail to transmit error codes, availability data, or utilisation metrics reliably. This undermines real-time discovery, payment integration, and fleet routing functions.

Interoperability across networks is also uneven. Roaming agreements are limited, resulting in fragmented user experiences. Payment interoperability is further constrained by inconsistent backend integrations. In contrast, European markets have matured roaming frameworks that enable users to access chargers across multiple operators with a single subscription.

Data governance presents a further challenge. Charging stations generate sensitive operational data that intersects with energy systems, vehicle behaviour, and grid load. India lacks a comprehensive regulatory framework governing this data. Without clear standards, data quality will remain inconsistent, affecting planning, grid coordination, and utilisation optimisation.

4.9 Workforce Limitations and Maintenance Challenges

Fast-charging infrastructure requires trained electricians, technicians, and power engineers capable of handling high-voltage systems. India faces shortages in this workforce, both in installation and maintenance. High-power chargers demand preventive maintenance, thermal system checks, calibration, and rapid repair capabilities. Delays in maintenance can render chargers non-operational for extended periods, contributing to the low energisation and high downtime problem.

The DST Roadmap warns that without a strong focus on skill development—especially in power electronics, safety systems, and thermal engineering—EV charging infrastructure will face operational unreliability.

4.10 Behavioural and Institutional Inertia

Charging infrastructure challenges are also shaped by behavioural constraints. Fleet operators accustomed to the high uptime and quick refuelling of diesel vehicles face uncertainties regarding EV charging times, queuing, energy availability, and potential operational disruption. Many transporters, particularly small operators, are reluctant to adopt EVs without guarantees regarding charging availability and operational predictability.

Institutionally, there remains hesitancy within utilities, municipal bodies, and even some state agencies to treat EV charging as essential public infrastructure. Without clear institutional ownership, decision-making remains slow and fragmented.

4.11 Summary

The roadblocks confronting EV charging infrastructure in India are multifaceted and deeply interconnected. The installed vs energised gap exposes a wider misalignment between charger deployment and electricity distribution readiness. The “time and space × 2x” factor intensifies challenges for commercial vehicles by amplifying real estate and operational burdens. Technical constraints in the grid, lack of indigenous high-power hardware, and thermal management challenges complicate fast-charging deployment. Land availability, regulatory fragmentation, financing gaps, and digital interoperability issues further restrict scale.

Addressing these barriers requires systemic coordination across policy, technology, manufacturing, real estate, and finance. The next chapter will build on this diagnosis to propose a structured set of recommendations, including end-to-end policy frameworks, technology pathways, financing strategies, and business model innovations.

CHAPTER-5

Recommendations: A System-Level Roadmap for India's EV Charging Infrastructure

India's transition toward electrified mobility—especially in commercial transportation—cannot succeed without a coordinated, systemic, and long-term strategy for EV charging infrastructure. The preceding chapters have established both the significant opportunity and the formidable roadblocks. The challenge now is to propose an integrated set of recommendations that respond to the technical, economic, spatial, institutional, and behavioural realities outlined earlier.

This chapter takes an explicitly systemic view. It argues that India must shift from fragmented, subsidy-driven deployment toward a strategic national charging architecture that integrates planning across land, grid, manufacturing, policy, digital systems, and mobility operations. The recommendations are grounded in the first-principles logic discussed in Chapter 1, particularly the "time–space × 2x utilisation factor," and incorporate the technical, infrastructural, and commercial complexities described in Chapters 2–4. They also build upon insights from the DST R&D Roadmap on Technologies to Overcome Hindrances to E-Mobility and the "Transforming Trucking in India" study.

The aim is to outline practical, evidence-based recommendations that can guide policymakers, industry leaders, utilities, urban planners, charging operators, and logistics companies in creating a future-ready charging ecosystem. The recommendations are grouped into six thematic pillars: (1) policy and governance, (2) land and infrastructure planning, (3) grid readiness and energy systems, (4) manufacturing and technology pathways, (5) financial and business-model innovations, and (6) digital architecture and unified platforms. A final subsection addresses the institutional and social dimensions of change.

5.1 Policy and Governance: Creating Long-Term Visibility and Stability

The first requirement for scaling EV charging infrastructure is the establishment of a coherent, stable, and predictable policy framework. Fragmented policies, frequent revisions, and lack of long-term visibility have historically contributed to investor hesitation and operational uncertainty. India can address this by implementing an integrated national EV charging policy with the following core principles.

A. A 15–20 Year National EV Charging Infrastructure Roadmap

India's charging ecosystem requires a dedicated long-term vision similar to national highway development programmes. A multi-phase roadmap—encompassing 2030, 2040, and 2047 milestones—would align investment, research, manufacturing, grid planning, and land-use decisions. Such a roadmap must explicitly recognise that commercial vehicles demand disproportionately higher charging capacity, larger sites, and more sophisticated technology.

Countries such as China and those in the EU have benefitted greatly from long-term certainty in charging standards, tariff structures, funding windows, and regulatory frameworks. India must adopt a similar approach: predictable policies are essential for the emergence of a mature industry capable of driving innovation.

B. Harmonisation of Regulations Across States

Differences in electricity tariffs, demand charges, land norms, tax structures, and state-level incentives create excessive complexity for operators. Harmonisation—through the Forum of Regulators, Ministry of Power, and a central inter-ministerial task force—can significantly reduce friction. The PM E-DRIVE scheme's structure of state nodal agencies is promising, but to achieve scale, state-level regulations must converge toward a national baseline.

C. Tariff Rationalisation for Public Fast Charging

High demand charges remain one of the most critical deterrents to PCS sustainability. The Ministry of Power has already permitted "EV charging as a service," but this must be strengthened through:

- a separate national tariff category for EV charging,
- peak/off-peak differentiated pricing, and
- exemption or rationalisation of demand charges for initial utilisation years.

For commercial EVs—whose operations are time-sensitive and synchronous—tariff predictability is essential for fleet electrification.

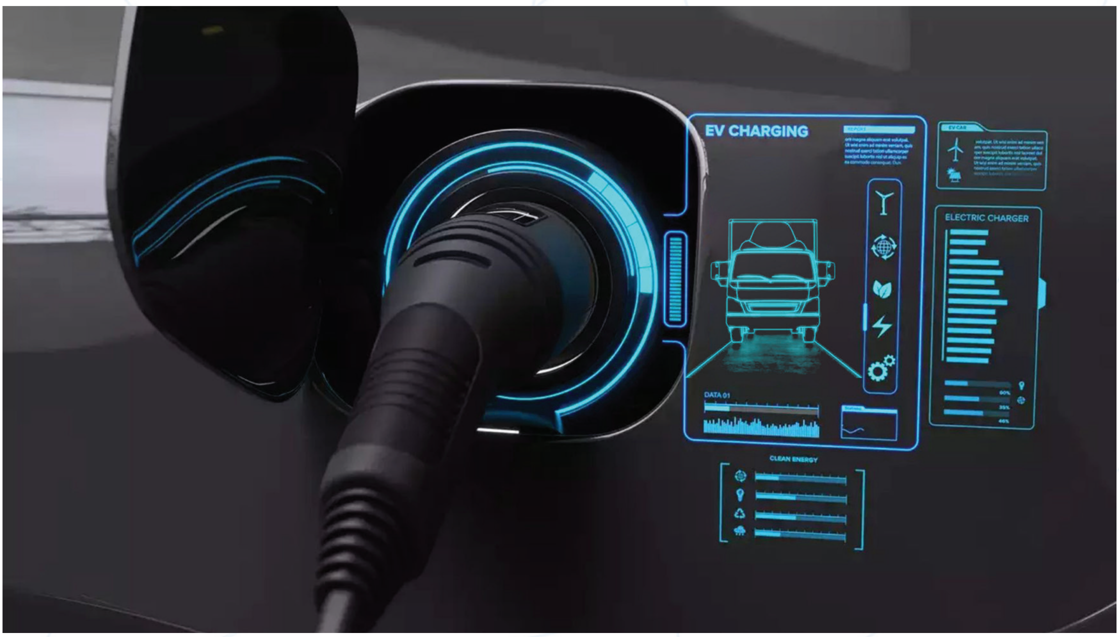
D. Mandatory ESG Disclosures for Logistics and Transport Sectors

India's logistics and trucking industry has historically been overlooked in the sustainability and emissions reporting ecosystem. Yet it contributes a substantial share of national emissions and diesel consumption. It is in this context that companies such as TCI, which was the first logistics firm in India to publish a sustainability and CSR report, serve as early exemplars of industry-led transparency.

This leadership should now inform policy. Government bodies, including SEBI and the Ministry of Corporate Affairs, should consider mandating emissions disclosures for medium and large logistics and transport companies. Mandatory ESG reporting will create positive pressure for fleet electrification, encourage structured planning, and catalyse demand for reliable charging infrastructure.

5.2 Land and Infrastructure Planning: Addressing the Spatial Crisis

The "time and space × 2x utilisation" challenge establishes that EV charging—especially for commercial vehicles—is fundamentally a spatial problem. Charging requires larger footprints, extended dwell times, queuing lanes, and circulation space, all of which are scarce in India's congested urban and peri-urban logistics zones.



A. National Land-Bank for Charging Infrastructure

India needs a centrally coordinated land-bank mechanism—similar to the land allocation policies historically used for fuel retailing. Public lands under agencies like NHAI, Railways, Defence Estates, State Industrial Development Corporations, and municipal bodies should be identified, zoned, and reserved for future PCS development.

This land-bank must classify parcels by suitability for different vehicle segments:small PCS for cars and LCVs,

- high-power hubs for buses and trucks, and
- ultra-high-power/MCS-ready sites for future freight corridors.

B. Integration of PCS into Urban Planning and Development Controls

Cities should embed charging requirements into development control regulations (DCRs), mandating:

- charging bays in new logistics parks,
- minimum EV readiness in commercial and industrial complexes,
- designated EV zones in transport nagars.

Such planning reforms are long overdue. Without explicit spatial provisions, PCS deployment will remain ad hoc and insufficient for CV-scale electrification.

C. Freight-Centric Charging Zones

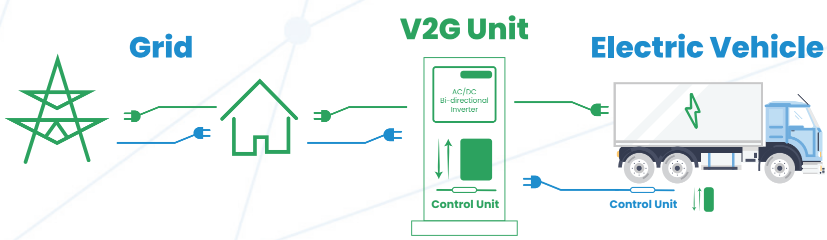
The ZET report stresses the importance of freight-oriented charging nodes—APMCs, industrial clusters, ports, warehouses. These zones must be pre-equipped with grid-ready charging plots or transformer pads. States like Maharashtra and Gujarat have already begun pilot initiatives; a nationwide framework would accelerate adoption.

5.3 Grid Readiness and Energy Systems: Building the Backbone of Charging

Charging infrastructure is ultimately constrained by grid readiness. The installed-vs-energised paradox reveals that charger deployment must be synchronised with electricity distribution upgrades.

A. Proactive Load Forecasting and Integrated Planning

DST Volume 3 identifies load forecasting as one of the weakest links in India's EV ecosystem. DISCOMs must adopt EV load models that project:



- spatial distribution of EV adoption,
- segment-wise energy requirements,
- peak-load scenarios, and
- infrastructure reinforcement needs.

These models must be integrated with city planning and the PM E-DRIVE nodal agency workflows.

B. Dedicated EV-ready Feeders and Fast-Track Grid Approvals

The approval cycle for new transformer installations, feeder upgrades, and substation enhancements must be compressed. A fast-track mechanism—similar to single-window clearance for renewable energy—would dramatically reduce energisation delays.

High-power hubs for buses and trucks should receive priority, given their high-impact nature and predictable usage.

C. Hybrid Renewable + Storage Solutions

Hybrid systems that combine grid supply, solar generation, and battery storage will be essential for both economic and technical reasons. They reduce peak load, lower electricity cost, enhance reliability, and support locations with limited grid capacity.

India should promote such hybrid systems through:

- viability gap funding (VGF),
- accelerated depreciation benefits,
- grid support tariffs, and
- concessional financing.

In this context, EKA Mobility's development of solar-powered charging systems – designed to bring operating costs for small commercial vehicles close to zero – illustrates the transformative potential of decentralised renewable charging.

D. Preparing for Megawatt Charging Systems (MCS)

Though still nascent in India, MCS will be indispensable for long-haul trucking. National R&D initiatives should prototype MCS systems under controlled programs, and NHAI should allocate land and power for MCS-ready highway nodes by 2030. DST Volume 3 highlights the need for indigenous high-power power electronics, thermal management, and connector localisation—areas where early investment will yield strategic benefits.

5.4 Technology and Manufacturing: Building Domestic Capability

To avoid future import dependence and reduce the cost of chargers, India must strengthen

domestic manufacturing of key components.

A. Domestic High-Power Charger Manufacturing India should localise production of:

- 30–350 kW DC chargers,
- liquid-cooled cables,
- power modules and rectifiers,
- thermal management units,
- pantographs and overhead systems for buses, and
- MCS components over the next decade.

DST Volume 3 identifies power electronics and thermal management as high-priority R&D areas with direct relevance to fast-charging scale-up.

B. Indigenous Power Semiconductor Ecosystem

A domestic supply chain for IGBT modules, SiC power devices, and high-frequency transformers is essential. This requires coordinated policy across the PLI schemes for semiconductors, electronics, and automotive technologies.

C. Interoperability and Standards Consolidation

India must reduce fragmentation in charger-vehicle communication standards. A clear national roadmap must outline:

- CCS2 for LCVs and cars,
- Pantograph standards harmonised with European and Chinese systems for buses,
- A phased pathway for MCS adoption for trucks.

Standards consolidation reduces costs, simplifies maintenance, and ensures reliability.

5.5 Business and Financing Models: Enabling Sustainable Operations

The financial viability of PCS requires structured business models that consider utilisation patterns, fleet partnerships, and operational risks.

A. Fleet–Charger Long-Term Contracts

Commercial fleets need predictable pricing and guaranteed availability. Operators need predictable utilisation. A long-term contract model—akin to power purchase agreements—can align both interests. Such contracts should be supported with digital access controls, dashboard tools, and shared risk mechanisms.

B. Aggregated Financing Models

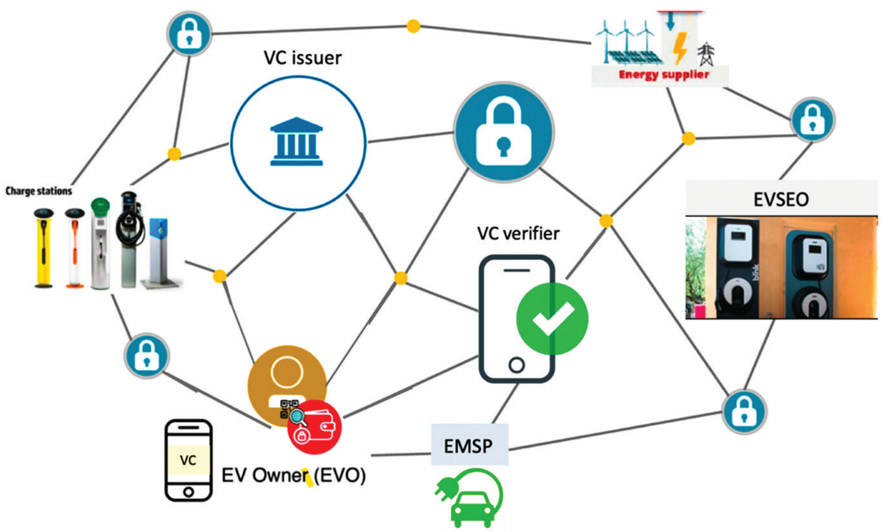
Charging infrastructure should be treated as core infrastructure, not as a retail electricity business. Specialised financing models—green bonds, pooled investment vehicles, infrastructure funds—can reduce cost of capital.

C. Charging-as-a-Service (CaaS) and Energy-as-a-Service (EaaS)

CaaS and EaaS models enable operators to avoid upfront capex. These models are particularly powerful for SMEs in logistics, who often lack capital but exhibit consistent utilisation needs.

D. Incentivising Battery-Buffered Charging

Storage-integrated PCS have economic benefits—peak shaving, arbitrage, reliability—but require incentives for adoption. A battery storage adder within PM E-DRIVE subsidies or a dedicated credit line could catalyse adoption.



5.6 Digital Architecture: Creating a Unified National Charging Ecosystem

Digitalisation is not an auxiliary requirement—it is the glue that binds mobility, electricity, and infrastructure systems into a functioning whole.

A. The National Unified EV Hub as a Core Public Utility

The Hub must evolve beyond discovery and payment into a full digital infrastructure layer enabling:

- real-time grid–charger coordination,
- utilisation prediction,
- energy optimisation,
- cross-operator roaming.

This requires mandatory, accurate, and standardised telemetry from all chargers.

B. Open Protocols and Interoperability

Strict OCPP adherence, common APIs, and unified payment rails must be enforced to prevent fragmentation. India should eventually move toward a roaming framework similar to Europe's eRoaming networks.

5.7 Institutional and Social Dimensions: Managing the Transition

Finally, EV charging infrastructure is not merely technological—it is organisational and behavioural. The resistance of fleet operators, institutional inertia within utilities, and fragmented mandates across agencies can impede progress.

A. Institutional Ownership

States should designate a single nodal agency with genuine authority to coordinate land, grid, planning, and PCS operations. This agency must have the ability to enforce timelines and monitor utilisation.

B. Capacity Building and Workforce Development

DST Volume 3 underscores the need for tens of thousands of trained technicians, power engineers, and safety professionals to maintain high-power chargers reliably.

A national skilling programme is essential.

C. Socialising the Economics of EVs

Fleet operators must be educated on total cost of ownership, operational planning, and electrification pathways. Demonstration corridors, public–private pilot hubs, and structured transition programs can ease the behavioural shift.

5.8 Summary

A robust EV charging infrastructure requires far more than charger installation. It demands a structured national vision, spatial planning reforms, integrated grid strategies, domestic technology development, innovative financing, and a strong digital backbone. The complexity of commercial vehicle charging—governed by time–space constraints and high-power requirements—makes systemic planning imperative.

India's success will depend not only on government policy but also on industry leadership. Companies such as TCI, through their pioneering sustainability disclosures, and EKA Mobility, through their innovative solar-powered charging solutions and commercial EV technologies, illustrate the direction in which the ecosystem must evolve: coordinated, transparent, technology-driven, and sustainability-aligned.

These recommendations create the foundation for the next chapter, which explores the human and institutional side of this transition through the Lippitt–Knoster Model for managing complex change.

CHAPTER-6

The Human Aspect of Change

We have covered technology, policy, and finance. However, infrastructure transformation is ultimately a human endeavour. To ensure these recommendations translate into reality, we must look at the Lippitt-Knoster Model of Complex Change and map it to the Indian EV context.

The Lippitt-Knoster model posits that for change to be successful, five elements must be present: Vision, Skills, Incentives, Resources, and an Action Plan. If anyone is missing, the result is predictable failure.

1. Vision (Missing = Confusion): The government has provided the Vision (Viksit Bharat, Net Zero). This is clear.
2. Skills (Missing = Anxiety): Do our mechanics and grid engineers know how to handle high voltage systems? Currently, there is a skills gap causing anxiety. We need massive upskilling programs (Skill India) focused on high-voltage safety and maintenance.
3. Incentives (Missing = Resistance): If DISCOMs see EVs only as a load burden and not a revenue source, they will resist. We must align incentives so that DISCOMs profit from EV charging (e.g., through Time-of-Day tariffs), turning resistance into support.
4. Resources (Missing = Frustration): This is the "Energized vs. Installed" gap. We have the chargers (Vision), but we lack the power connection (Resource). Ensuring grid availability is the key to removing frustration.
5. Action Plan (Missing = False Starts): Without a coordinated roadmap, we have sporadic starts—chargers installed where there are no EVs, and EVs where there are no chargers. A National Action Plan for EV Corridors is the final piece of the puzzle.

We strongly believe, by addressing the human and systemic elements of this change, India can move from a state of "False Starts" to sustainable, scalable success.

CHAPTER-7

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Disclaimer:

The views expressed are solely that of the author.

Company Profile

EKA Mobility is an Indian electric vehicle manufacturer driving the transition to sustainable commercial mobility. Headquartered in Pune and backed by the Pinnacle Industries Group, the company designs and manufactures zero-emission electric vehicles across buses, trucks, small commercial vehicles, and last-mile mobility segments.

EKA combines advanced automotive engineering with smart digital solutions to deliver reliable, efficient, and scalable EVs for public transport and logistics. With a strong focus on innovation, quality, and sustainability, EKA Mobility is supporting India's green mobility ambitions while building a future-ready electric commercial vehicle ecosystem for domestic and global markets.

Author Profile :

With over 30 years of experience, Mr. Hirdesh is the former founder of an electric two-wheeler company and a lithium-ion battery pack factory. He has a strong background in developing new business ventures in defense, railways, and solid waste management. At EKA, he is responsible for Business Strategy and Technology Management, driving key innovations and growth.

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From Farm to Fleet: The Significance of Biofuels in Green Logistics

By – Dr. Aditya Gupta, Chief Operating Officer - TCI–IIMB Supply Chain Sustainability Lab

Supply Chain Sustainability Lab

1. Introduction: The Decarbonisation Imperative in Logistics

Logistics is the backbone of modern economies—but it is also one of the most carbon-intensive components of global value chains. Freight transportation alone accounts for a significant and growing share of global greenhouse gas (GHG) emissions, driven by expanding trade volumes, e-commerce growth, and rising consumer expectations for speed and reliability. According to IEA, transportation accounts for approximately 24% of global CO2 emissions, with logistics and freight contributing significantly to this figure. In India, freight transportation alone accounts for close to 7% of the national emissions. Unlike passenger mobility, logistics faces a unique challenge: heavy payloads, long distances, tight delivery schedules, and limited downtime for refuelling or charging.

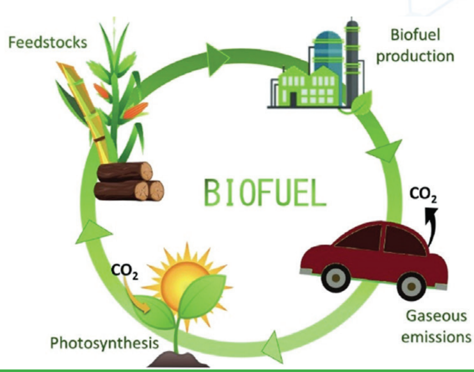
Logistics remains a hard-to-abate sector. While electrification (EV) and hydrogen promise deep decarbonisation in the long term, their scalability, infrastructure requirements, and cost trajectories mean that they cannot deliver emission reductions at the pace required over the next decade.

It is in this context that biofuels assume strategic importance. Often positioned as a transitional solution, biofuels offer an immediate and pragmatic pathway to reduce emissions from freight transport without waiting for disruptive technological shifts. Rather than being viewed as a competing alternative to EV, biofuels should be understood as an enabling bridge in the journey towards green logistics.

2. What Are Biofuels?

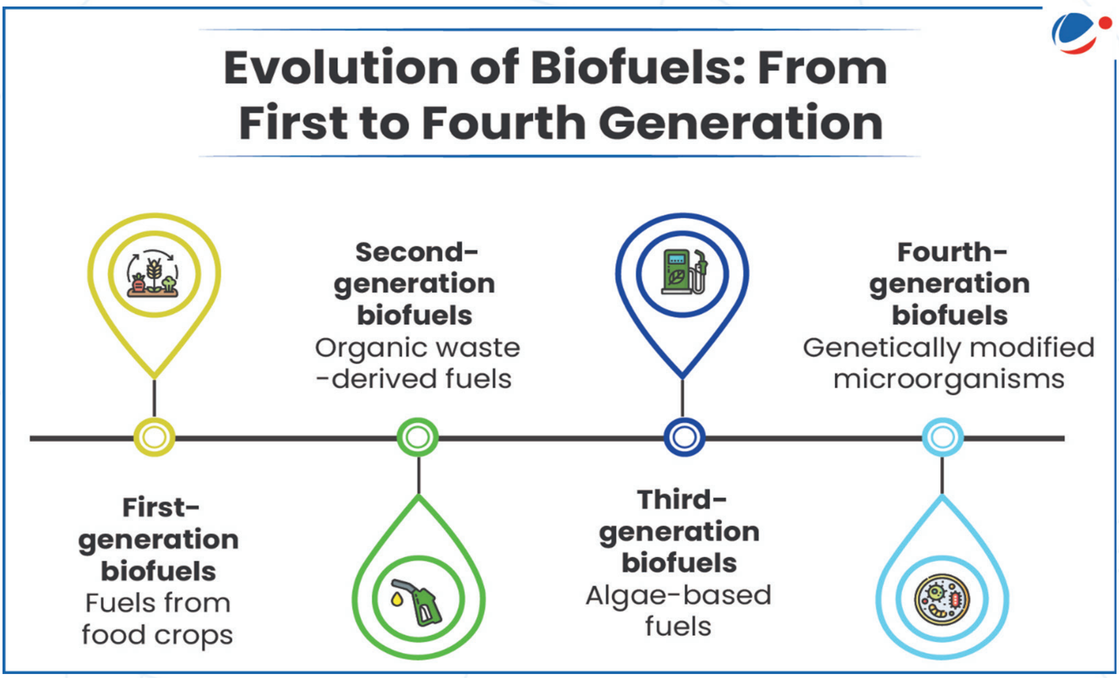
Biofuels are fuels derived from biological sources such as crops, agricultural residues, organic waste, and biomass. Their key advantage is the carbon cycle: the CO_2 released during combustion was recently absorbed from the atmosphere by the plants used as feedstock, creating a near-neutral cycle compared to the release of ancient, geologically stored carbon from fossil fuels.

From a logistics perspective, their relevance lies not in their chemistry alone, but in their compatibility with existing vehicles, infrastructure, and operating models.



However, not all biofuels are created equal. The industry is categorized into "generations" defined by feedstock and sustainability:

- **First-Generation:** Derived from sugar, starch, or vegetable oil crops like corn, sugarcane, and palm oil. While they pioneered the market, they sparked the legitimate "food vs. fuel" debate, raising concerns over land-use change, water use, and food prices.
- **Second-Generation (Advanced Biofuels):** This is where the true potential for logistics lies. Made from non-food biomass, they utilize waste streams: used cooking oil (UCO), agricultural residues (straw, corn stover), forestry waste, and the organic fraction of municipal solid waste. They offer superior greenhouse gas (GHG) savings—often exceeding 70% compared to fossil fuels—without competing with food supply.
- **Third-Generation:** An emerging frontier focusing on algae, which can grow on non-arable land and absorb significant CO_2. While promising, commercial scalability remains a future prospect.

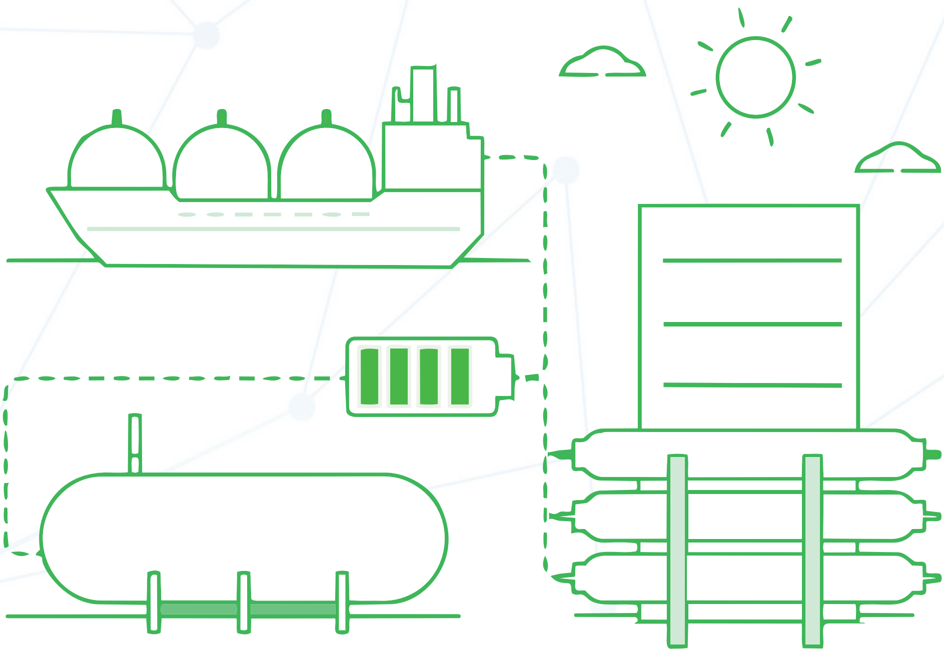


Source: https://dce.visionias.in/

However, not all biofuels are created equal. For the logistics industry, which requires scalable, sustainable, and practical solutions, several key types of biofuels are significant, with a critical focus on advanced, waste-based variants:

1. **Ethanol:** The most widely produced biofuel globally, traditionally fermented from sugar or starch crops like corn and sugarcane (first-generation). Its primary relevance for logistics lies in its blended form (e.g., E10, which is 10% ethanol mixed with 90% petrol), used in standard petrol-powered freight vehicles. However, the future of ethanol in heavy transport is moving toward advanced cellulosic ethanol, made from agricultural residues (e.g., corn stover, straw) or forestry waste. This "second-generation" ethanol offers a far superior carbon intensity profile and represents a promising pathway for decarbonizing certain segments of the transport fleet without competing with food supply.

2. **Hydrotreated Vegetable Oil (HVO) / Bio- Diesel:** This is a premier, high-quality drop-in fuel for diesel engines. Produced by treating waste fats, used cooking oil, or vegetable oils with hydrogen, it is chemically similar to fossil diesel. Its greatest logistical advantage is its flexibility: it can be used in pure form (HVO100) or blended in any proportion in existing diesel trucks, ships, and machinery without any engine modifications, offering immediate greenhouse gas reductions of up to 90% on a lifecycle basis.
3. **Biomethane (Bio-CNG/Bio-LNG):** This is renewable natural gas produced from the anaerobic digestion of organic waste—such as agricultural slurry, food waste, or landfill gas. Once purified and compressed (Bio-CNG) or liquified (Bio-LNG), it serves as a direct substitute for fossil natural gas. For logistics, Bio-LNG is particularly crucial for long-haul heavy-duty trucks and as a marine fuel, providing the necessary range and energy density while dramatically cutting particulate matter and NOx emissions alongside carbon.
4. **Sustainable Aviation Fuel (SAF):** While SAF can be produced via multiple pathways, the most commercially advanced and scalable today is the HEFA (Hydro processed Esters and Fatty Acids) pathway, which is essentially a specific, tightly regulated production of bio-jet fuel from the same waste feedstocks as HVO. SAF is not merely an option but an existential priority for air cargo and aviation logistics. It is the only viable tool currently available to significantly decarbonize aviation, as it meets the strict performance and safety standards for jet engines and can be blended with conventional jet fuel (up to 50% currently). For green logistics, SAF represents the key to maintaining global air freight connectivity in a net-zero world, making it arguably the most strategically significant advanced biofuel of all.



Together, these fuels—from established Ethanol blends for light fleets, to versatile HVO for diesel assets, Biomethane for natural gas fleets, and the critical SAF for aviation—form a versatile toolkit that directly addresses the decarbonization needs across the entire logistics spectrum, from local delivery to long-haul trucking, shipping, and air freight.

3. The Strategic Fit: Why Biofuels Are a Game-Changer for Logistics

The significance of biofuels for logistics is not merely that they are renewable, but that they solve specific, critical challenges in the sector's decarbonization journey.

A. The "Drop-In" Advantage: Decarbonization Without Disruption

The most compelling argument for biofuels is their compatibility. The global logistics system runs on a multi-trillion-dollar infrastructure of internal combustion engines, fueling stations, pipelines, and tankers. Replacing this overnight is impossible. Biofuels can utilize this existing infrastructure immediately.

Key advantages include:

- **Immediate impact:** Biofuels reduce tailpipe and lifecycle emissions from day one.
- **Infrastructure reuse:** Existing fuel distribution, storage, and refuelling infrastructure can often be leveraged.
- Fleet continuity: Operators avoid premature asset retirement and capital-intensive fleet replacement.
- **Operational familiarity:** No major changes in routing, scheduling, or driver behaviour are required.

From a carbon accounting perspective, biofuels directly contribute to reductions in Scope 1 emissions for fleet operators and Scope 3 emissions for shippers and cargo owners. This makes them particularly attractive for companies facing near-term ESG targets, science-based commitments, or regulatory pressure.

B. Taming the "Hard-to-Abate" Giants

Electrification faces steep hurdles in energy density, refueling/charging time, and infrastructure cost for certain transport modes. Biofuels are uniquely positioned here:

Maritime Shipping: International shipping carries 80-90% of world trade. The industry's fuel of choice, heavy fuel oil, is notoriously dirty. Battery-electric ships are feasible only for short routes. Green ammonia or hydrogen are long-term options but require entirely new engine and bunkering infrastructure. Biofuel blends (B30, B100) are being trialed right now by giants like Maersk and CMA CGM as the most viable mid-term decarbonization lever for the existing global fleet.

Long-Haul & Heavy-Duty Trucking: While electric trucks are emerging for regional hauls, the economics and charging logistics for cross-continental routes remain challenging. Renewable diesel (HVO) and Bio-LNG provide the range, power, and rapid refueling that match current operational patterns, making them the leading low-carbon choice for many fleet operators today.

Aviation and Air Cargo: Battery density makes full electrification of long-haul flights a distant dream. Sustainable Aviation Fuel (SAF), over half of which is currently derived from advanced biofuel pathways like HEFA (from waste oils), is the only commercially viable tool the aviation industry has to significantly reduce emissions in the coming decades.

C. A Bridge and a Complementary Pillar

It is crucial to frame biofuels not as a competitor to electrification or hydrogen, but as a strategic partner in a multi-fuel future. They act as:

- **A Bridge:** Decarbonizing the massive existing asset base during the 20-30 year transition to zero-tailpipe-emission technologies.
- **A Complement:** They will likely remain essential in niches where other technologies are less feasible, such as in backup generators for logistics hubs, in certain agricultural and mining logistics (remote operations), and as a carbon-neutral component in future synthetic fuel (e-fuels) production

Common Myths About Biofuels

- **Myth:** Biofuels are always bad for food security

  Reality: Waste-based biofuels avoid food–fuel trade-offs
- **Myth:** Biofuels delay electrification

  Reality: They enable emissions reduction while alternatives like EV scale
- **Myth:** Biofuels are not scalable

  Reality: Supply-chain design, not technology, is the bottleneck

4. Biofuels and Green Logistics: The Indian Context

The Indian context for biofuels and green logistics is defined by a powerful trifecta: acute energy import dependency, severe urban air quality challenges, and a formidable commitment to climate action under the Paris Agreement. Recognizing biofuels as a strategic lever to address all three, India has crafted one of the world's most ambitious and structured national biofuel policies.

A. Targets: The 2030 Vision

The Indian government has set forth unambiguous and ambitious national goals to drive the biofuel economy:

1. **Ethanol Blending Target:** Achieve 20% ethanol blending in petrol (E20) nationwide by the ethanol supply year 2025-26. This target was aggressively brought forward from the original 2030 goal, signalling high-level political commitment.
2. **Biodiesel Blending Target:** Achieve a 5% blending of biodiesel in diesel by 2030, with an initial focus on sourcing from non-edible oilseeds and used cooking oil.
3. **Bio-CNG/Biogas Target:** Under the SATAT (Sustainable Alternative Towards Affordable Transportation) scheme, the goal is to establish 5,000 commercial compressed biogas (CBG) plants by 2024-25 to produce 15 million metric tonnes of CBG annually, directly targeting the heavy transport and logistics fuel supply.
4. **SAF:** In aviation, a 5% biofuel blend for international flights is targeted by 2030 to comply with global standards

These targets support broader commitments, including reducing emissions intensity by 45% by 2030 under the Paris Agreement and achieving net-zero by 2070.

B. Policy Support: A Comprehensive Toolkit for Implementation

To convert these targets into reality, the government has enacted a multi-pronged policy ecosystem:

Policy / Scheme	Year Launched / Updated	Key Targets/ Provisions	Relevance for Green Logistics
National Policy on Biofuels (NPB)	2018 (amended 2022)	• Expanded feedstocks (food grains, residues, waste) • Promotion of 2G & advanced biofuels • Viability Gap Funding for advanced biofuels	Provides overarching policy framework enabling large-scale biofuel production for transport fuels
Ethanol Blended Petrol (EBP) Programme	2003 (accelerated post-2018)	• 20% ethanol blending target by 2025–26 • Assured offtake by OMCs • Differential ethanol pricing	Reduces fossil fuel use in road transport; indirectly supports green logistics through fuel decarbonisation
SATAT (Sustainable Alternative Towards Affordable Transportation)	2018	• Target of 5,000 Compressed Biogas (CBG) plants • Long-term CBG offtake by OMCs	Critical for bio-CNG adoption in freight trucks, buses, and logistics fleets
GOBARdhan Scheme	2018 (revamped 2021)	• Waste-to-wealth using agri residue & organic waste • Integration with CBG and bioenergy projects	Strengthens feedstock availability and circular economy linkages for biofuels

Policy / Scheme	Year Launched / Updated	Key Targets/ Provisions	Relevance for Green Logistics
Sustainable Aviation Fuel (SAF) Roadmap	Announced 2023–24	• Blending targets: 1% by 2027, 2% by 2028, 5% by 2030 • Alignment with CORSIA norms	Essential for decarbonising air cargo and express logistics
India's Long-Term Low Emissions Development Strategy (LT-LEDS)	2022	• Net Zero by 2070 • Transport decarbonisation via biofuels, EVs, hydrogen	Explicitly positions biofuels as transition fuels for hard-to-abate sectors
Updated Nationally Determined Contribution (NDC)	2022	• 45% reduction in emissions intensity of GDP by 2030	Reinforces urgency for low-carbon freight and logistics solutions
PLI & Capital Subsidies for Bioenergy	Ongoing (2019 onwards)	• Capital support for bioenergy & ethanol plants	Improves economics and scaling of biofuel supply chains
Carbon Market Framework (Indian Carbon Market – ICM)	Notified 2023	• Framework for future carbon trading & credits	Improves long-term competitiveness of biofuels via carbon pricing

C. Progress So Far: Accelerating Momentum

The results of this target-policy alignment are now evident, particularly in the ethanol sector:

- **Ethanol Blending:** India has seen a transformational leap, moving from about 1.5% blending in 2013-14 to over 12% in 2022-23. Ethanol production capacity has expanded to 15 billion liters by 2025, supported by diversified feedstocks including sugarcane, grains, and cellulosic materials. In July 2025, blending reached 19.93%, and by year-end, full compliance was realized, saving billions in oil imports and creating rural jobs.
- **Advanced Biofuels and CBG:** Progress here is in the build-out phase. While biodiesel blending remains low, the RUCO (Repurpose Used Cooking Oil) initiative is creating an ecosystem for UCO collection and conversion. For CBG, several plants have been commissioned under SATAT, with many more in the pipeline, though the 2024-25 target for 5,000 plants is challenging and will require accelerated investment.

The Indian model demonstrates how binding targets, coupled with feedstock-flexible policies and guaranteed procurement, can rapidly scale a biofuel ecosystem, turning national ambitions for energy independence (Atmanirbhar Bharat) and net-zero into actionable ground-level progress for greener logistics.

5. Navigating the Challenges: A Reality Check

No solution is perfect, and a credible discussion of biofuels must address their limitations and controversies.

- **Feedstock Sustainability & The "ILUC" Ghost:** The specter of Indirect Land-Use Change (ILUC)—where biofuel crop production displaces food crops, pushing agriculture into forests—haunts first-generation biofuels. The industry's response is advanced biofuels from verified waste and residue streams. Robust, internationally recognized certification schemes like the International Sustainability and Carbon Certification (ISCC) and the Roundtable on Sustainable Biomaterials (RSB) are critical to ensure genuine carbon savings and no ecosystem harm.
- **The Scalability Dilemma:** Current global production of advanced biofuels is a fraction of the demand from the transport sector. Scaling up requires sustained investment in biorefineries. While waste feedstocks are abundant, they are also geographically dispersed, creating complex collection and supply chain logistics.
- **Supply Chain Challenges:** Logistics-specific challenges include feedstock supply chain complexities—transporting bulky biomass increases emissions—and infrastructure issues, like biofuel corrosiveness in pipelines.
- **The Cost Factor:** Advanced biofuels are typically more expensive than their fossil counterparts, though the gap fluctuates with oil prices and carbon taxes. Wider adoption hinges on policy support (subsidies, mandates) and the internalization of the social cost of carbon—recognizing that the higher price reflects the avoidance of environmental damage.

Mitigation strategies involve shifting to second- and third-generation fuels, improving regulations, and investing in R&D to enhance yields and reduce costs.

Source:://https://www.freepik.com//

6. Case Studies and Real-World Applications

Real-world examples illustrate biofuels' impact in logistics.

- In shipping, Maersk has pioneered biofuel blends, achieving a significant emission reduction on select routes using second-generation biofuels from waste oils. Their pilot with the Mette Maersk vessel demonstrated seamless integration, with a potential of cutting CO2 by thousands of tons annually.
- For road logistics, CEVA Logistics converted 14 trucks in France and 69 in Italy to hydrotreated vegetable oil (HVO), a biofuel which can reduce emissions by up to 90% without engine changes.
- UPS and DHL have similarly adopted biofuel fleets, reporting cost savings from incentives and improved corporate sustainability ratings.
- In aviation, United Airlines' use of SAF from municipal waste has decarbonized flights, with projections showing biofuels could meet 5-10% of global aviation fuel by 2030.
- Brazil's ethanol program, blending up to 27% in gasoline, exemplifies national-scale success, reducing transport emissions and creating jobs.

These cases highlight measurable benefits: Emission cuts, regulatory compliance, and operational resilience, though initial investments were offset by long-term gains.

7. Conclusion: Fuelling a Pragmatic Transition

The journey to green logistics is a marathon, not a sprint. In this race, advanced biofuels are not a silver bullet, but they are a critical and available-now baton that can be passed immediately to reduce emissions while the longer-term solutions reach the finish line.

Their unique value proposition is undeniable: immediate compatibility, profound carbon cuts in hard-to-electrify sectors, and the creation of circular economic loops. They embody a pragmatic approach to decarbonization—one that starts today with the infrastructure and vehicles we have.

The ultimate destination is a multimodal, highly efficient, net-zero supply chain. In that future system, batteries will power last-mile vans, hydrogen may propel heavy trucks, and green ammonia could sail ships. But getting there requires a transition powered by smart, sustainable choices today. By embracing certified advanced biofuels, the logistics industry can fuel its own revolution, driving not just goods, but meaningful climate progress, one shipment at a time.

Disclaimer:

The views expressed are solely that of the author.

Company Profile

TCI-IIMB Supply Chain Sustainability Lab is a research facility founded by Transport Corporation of India Ltd (TCI) and IIM Bangalore in the year 2023. Situated in the premises of IIMB, as a part of the Supply Chain Management Center at IIM Bangalore it conducts research in areas such as decarbonisation of transportation, circular economy and sustainable procurement, and publishes white papers, case studies and thought leadership articles on sustainable supply chain management topics. It offers consulting services on carbon-related mapping, measurement, mitigation and management. It targets to provide certification and assessment services, such as supplier sustainability assessment. It has initiated multiple research projects, white papers and case studies and is partnering with other organizations in similar domains. This is one-of-its kind centre of excellence in sustainable supply chain practices, dissemination and advocacy.

Supply Chain Sustainability Lab

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