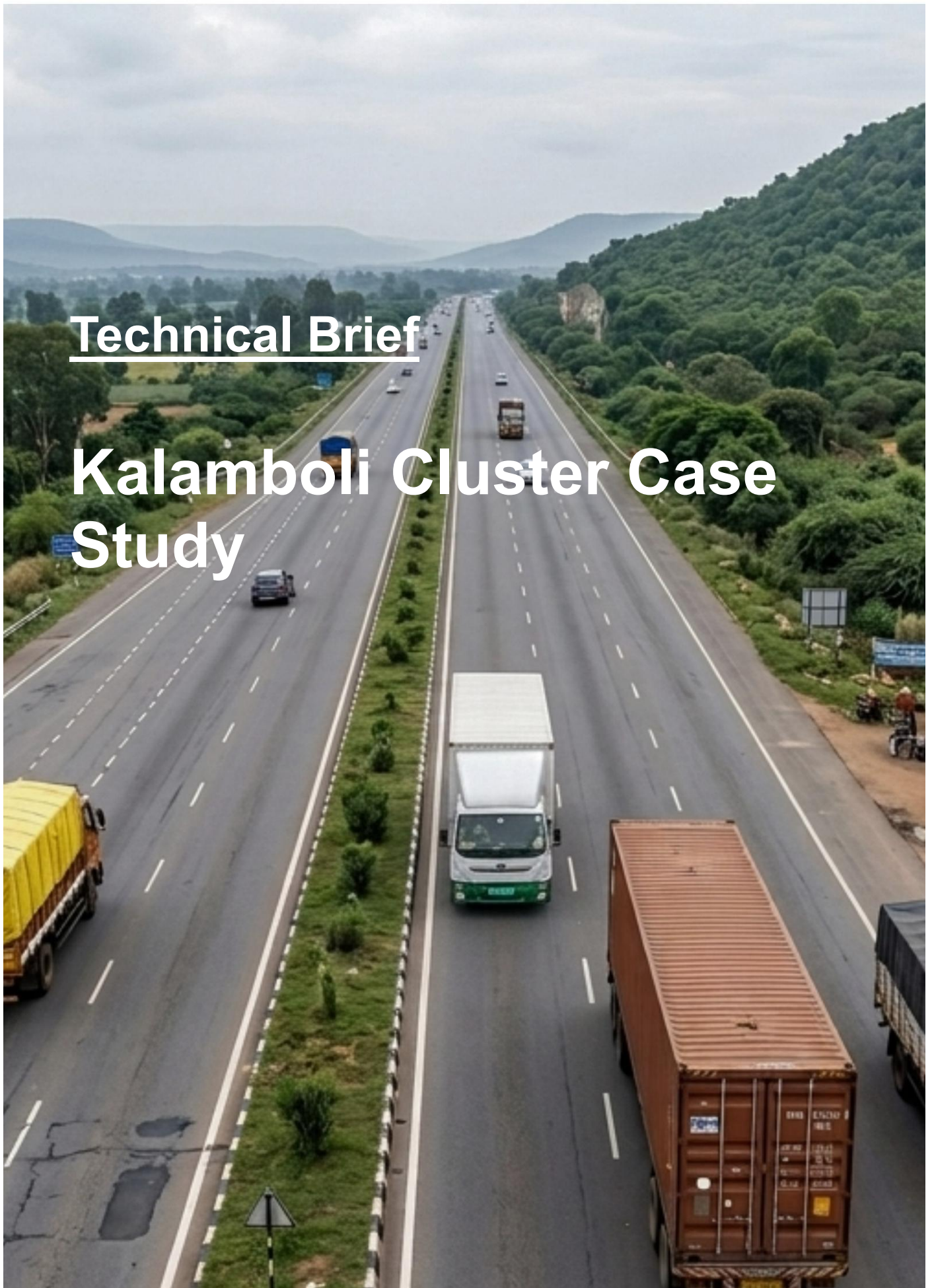


Technical Brief

Kalamboli Cluster Case Study



Context

India's truck fleet is on a steep growth curve. As urbanisation accelerates and e-commerce continues to reshape supply chains, the country's truck fleet is expected to grow four-fold to nearly 17 million vehicles by 2050¹, driving freight movement to 9.6 trillion tonne-km². This has major implications on the environment and India's energy economy. Today, road freight consumes a quarter of India's oil imports, translating to an expenditure of INR 3.3 lakh crore in FY 2022–23³, alone. It is also one of the largest contributors to transport-related pollution, accounting for 34% of CO₂ emissions and 53% of PM emissions from the road transport sector⁴. Electrifying freight isn't just an option anymore; it's the clearest lever India has to rein in both emissions and energy costs. The upside is substantial. By 2050, Zero-Emission Trucks (ZETs) could displace the need for 993 billion litres of diesel, unlocking over ₹116 lakh crore in fuel savings while avoiding 2.8–3.8 gigatonnes of cumulative CO₂ emissions.⁵

To support this transition, several pilots are being undertaken across industrial, mining, and port sectors. One notable initiative is the launch of 50 battery-swappable electric heavy trucks under a pilot by the Jawaharlal Nehru Port Authority (JNPA), which aligns with JNPA's ambitious target of achieving the 90% conversion of its 600-truck fleet to EVs by 2026⁶. Complementing these localized efforts, the central scheme PM E-Drive has dedicated purchase incentives for 5,643 e-trucks across the N2 and N3 categories, with a budget overlay of INR 500 crores⁷. These policy developments, coupled with growing industry interest, indicate that India could witness rapid growth in ZET adoption over the coming decades. However, such growth will also create significant electricity demand due to the large battery capacities and charging requirements of heavy-duty vehicles. If India achieves an 86% ZET sales penetration in the Medium Duty Truck (MDT) and Heavy-Duty Truck (HDT) segments by 2050, the energy demand from charging the Battery Electric Truck (BET) stock in 2050 is estimated to be as high as 531 terawatt-hours (TWh)⁸. This scale of demand raises a critical question: Is India's electricity grid prepared for the freight electrification transition?

Decarbonising freight, however, is only as fast as the grid supports it. This brief explores that question through a real-world lens by examining the potential ZET adoption pathway and associated grid implications for the Kalamboli freight cluster in Navi Mumbai, Maharashtra.

¹ Office of the PSA, GOI, 2025. [India's Priority Corridors for Zero-Emission Trucking](#)

² Office of the PSA, GOI, 2024. [Bharat Zero Emission Trucking \(ZET\) Policy Advisory](#)

³ Office of the PSA, GOI, 2024. [Bharat Zero Emission Trucking \(ZET\) Policy Advisory](#)

⁴ Office of the PSA, GOI, 2025. [India's Priority Corridors for Zero-Emission Trucking](#)

⁵ Office of the PSA, GOI, 2025. [India's Priority Corridors for Zero-Emission Trucking](#)

⁶ PIB, 2025. [India's First Fleet of EV Trucks with Swappable Batteries Flagged Off at JNPA by Shri Sarbananda Sonowal](#)

⁷ PIB, 2026. [Promotion of Electric Vehicles](#)

⁸ NITI Aayog, RMI, 2022. [Transforming Trucking In India: Pathways to Zero Emission Truck Deployment, September 2022.](#)

Why Kalamboli?

2.1 A Freight Hub Built for Electrification

Kalamboli, strategically positioned 21 km from Jawaharlal Nehru Port Authority (JNPA) at the convergence of NH-48, NH-66, the Sion-Panvel Expressway, and the Mumbai-Pune Expressway, the 300-hectare Kalamboli node functions as Asia's largest steel market and a critical EXIM staging hub for the Mumbai-Pune industrial corridor.

Kalamboli was selected for this study due to its high concentration of short- and medium-haul freight operations associated with JNPA, nearby industrial clusters, and the steel market ecosystem. Traffic estimates indicate a freight volume of approximately 18,000 trucks per day⁹(calculated), while the corridor supports 10,000–12,000 MT of bulk commodities such as steel and cement, along with 2,100–2,450¹⁰(calculated) daily EXIM container truck movements. This dense and repetitive freight activity creates an ideal operating environment for electric trucks, where predictable routes and high vehicle utilization improve cost competitiveness. Furthermore, the node's mature industrial ecosystem and existing power infrastructure make it well suited for the development of centralized charging depots and supporting grid infrastructure.

2.2 Congestion Bottlenecks, Modernization, and ZET Potential

The node's traffic density comes at a cost. Port-bound diesel trucks currently face delays ranging from 8 to 24 hours to clear the area, leading to prolonged idling, increased operating costs and localised air pollution, AQI levels in nearby Navghar, Navi Mumbai swing between 40 and 204 (World AQI Map).

To address these challenges, two major infrastructure projects are currently underway. These include the ₹1,252 crore Kalamboli Junction modernization (including a ₹482 crore, 7-flyover signal-free interchange) and a ₹4,500 crore, 6-lane access-controlled JNPA-to-Chowk Greenfield Highway approved in March 2025.

Against this backdrop of freight growth and infrastructure transformation, this analysis models the energy demand that ZET deployment at Kalamboli would create, drawing on localised fleet mix data, cycle times, and restriction windows. The objective is to develop a scalable framework for freight electrification that can be replicated across India's major port-hinterland logistics corridors.

⁹ PIB, 2025. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2112783®=48&lang=2>

¹⁰ LDB, Dec 2025 & Mar 2026. https://www.jnport.gov.in/uploads/pdf/ia_report/121/LDB_Report_Dec_2025.pdf
https://www.jnport.gov.in/uploads/pdf/ia_report/124/PW0001_March_2026.pdf



Figure 2.2: JNPA, Kalamboli logistics cluster, and associated transport connectivity network.

E-Truck Potential and Projected Demand

To understand the implications of freight electrification on charging infrastructure and grid planning, this study focuses on two high-potential freight applications within the Kalamboli cluster. These use cases were selected based on their high freight volumes, predictable operating patterns, relatively short haul lengths, and strong potential for centralized charging infrastructure deployment.

Beyond their individual characteristics, these applications demonstrate the importance of **demand aggregation** in accelerating heavy-duty freight electrification. Aggregating freight demand across multiple users, industries, and logistics operations creates the scale required to improve electric truck utilization, enhance charging infrastructure economics, reduce investment risks, and enable more efficient grid planning. The Kalamboli cluster presents a particularly compelling opportunity due to the concentration of industrial freight activity, captive operations, and port-linked logistics flows within a relatively compact geography.

Two use cases are explored here:

3.1 Railway Goods Shed to “Kalamboli Steel Market”

The first use case examines the movement of hot rolled and cold rolled steel coils, heavy machinery, and other bulk commodities between railway goods sheds and the Kalamboli steel market. This operation is characterized by short trip distances (3–30 km per round trip), high vehicle utilization, and repetitive daily operations, making it particularly suitable for battery electric truck deployment.

The corridor currently supports the movement of approximately **10,000–12,000 tonnes of steel and bulk commodities per day**, requiring an estimated fleet of **55–65 heavy-duty trucks** operating in captive shuttle configurations. The centralized nature of these operations creates an opportunity for

shared depot charging infrastructure with high charger utilization rates and limited grid connection points.

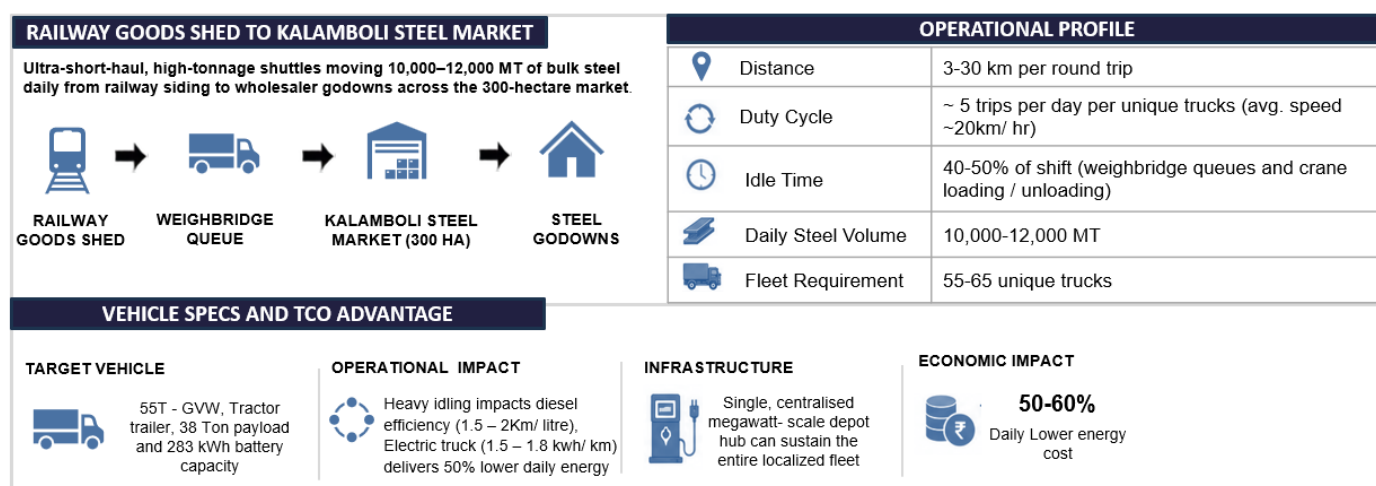


Figure 3.1: Use case operational and economic profile.

3.2 Container Freight Stations (CFS) to JNPT

The second use case evaluates freight movements between container freight stations (CFSs), empty container yards, and JNPA terminals. This corridor serves as the primary hinterland staging network for India's largest container port, supporting approximately 2,100–2,450 container truck movements per day.

Although operations are influenced by vessel schedules, port gate congestion, and variable dwell times, the relatively short operating distances and high concentration of freight activity make this segment a strong candidate for phased electrification. The aggregation of container movements across multiple operators and facilities creates a sufficiently large and predictable demand base to support centralized charging infrastructure and coordinated grid planning.

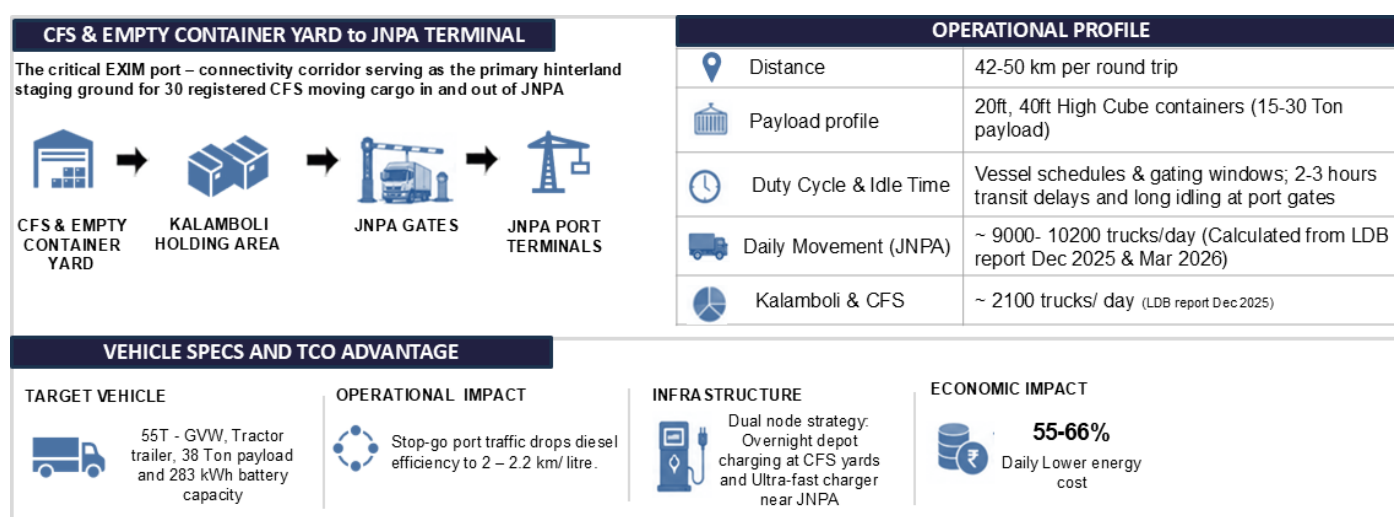


Figure 3.2: Use case operational and economic profile.

Aggregated Electrification Potential: Together, these two freight applications represent an aggregated electrification opportunity ranging from approximately 217 trucks under a 10% adoption scenario to more than 2,164 trucks under a full electrification scenario. This level of demand aggregation is significant because it transforms freight electrification from isolated vehicle deployments into a cluster-based infrastructure planning exercise.

What Does It Mean for the Grid and Charging Strategies?

2164 (64 captive steel shuttles + 2100 targeted CFS-linked container trucks) heavy-duty trucks operating in the Kalamboli cluster present a significant opportunity for phased electrification. To understand its implications, four adoption scenarios (10%,30%,50% and 100%) were evaluated to assess the charging infrastructure needs and grid impact.

Under a business-as-usual charging pattern, i.e. overnight charging, the e-truck adoption can generate need for 46, 137, 229, 457 CCS II fast chargers, for 10%, 30%, 50% and 100% e-truck adoption scenarios, respectively, translating into additional sanctioned loads of approximately 5.5 MW, 15.4 MW, 27.5 MW, and 54.8 MW.

Figure 4 illustrates how different charging patterns influence charging infrastructure needs and sanctioned load across varying levels of truck electrification.

ZET Penetration →		10%	30%	50%	100%
Overnight	No of Chargers	46	137	229	457
	Grid Impact (Kwh)	5,520	16,440	27,480	54,840
Day and Overnight Charging	No of Chargers	35	103	172	343
	Grid Impact	4,200	12,360	20,640	41,160
Morning, Day and Overnight Charging	No of Chargers	23	69	115	229
	Grid Impact	2,760	8,280	13,800	27,480

Figure 4: Charging infrastructure needs and grid impact for Kalamboli cluster under different EV penetration and charging scenarios.

4.2 Key Insights From Our Analysis

- Grid impact:** At 100% penetration, the charging demand from the Kalamboli cluster alone could add over 55 MW of load to the grid, underscoring the importance of proactive grid planning and robust charging infrastructure siting strategies for such industrial clusters. This indicates that for industrial clusters like Kalamboli, preparing for electric vehicle transition will require not only fleet electrification strategies but also timely investments in charging infrastructure and grid readiness.
- Shifting charging demand:** Our analysis has shown that shift in charging patterns of trucks can be just as important as the fleet size. Shifting just 25% of charging demand from overnight hours to daytime charging could reduce charger requirements and associated sanctioned load by nearly 24% and moving an additional 25% of the charging demand to morning hours, could further cut it by almost 50%. Thus, shifting of charging patterns can reduce both infrastructure investment and grid impact. Moreover, aligning charging demand with daytime and morning hours increases the opportunity to utilize solar energy, making electric truck operations both cost-effective and greener.
- Detailed on-ground studies:** As commercial operations are highly time sensitive with vehicle availability and delivery reliability being paramount, any modification to charging schedules must be grounded in real-world operational constraints. Thus, detailed studies are needed to identify which of the charging sessions can be shifted without affecting delivery timelines and service

commitments, enabling the development of practical charging strategies that support efficient grid integration. One such analysis has been conducted for Delhi-Jaipur corridor where smart charging strategies were evaluated for electric trucks based on existing truck operations and electrification projections, to understand the impact and benefits of such strategies¹¹.

While the projected demand indicates the scale of charging infrastructure required, ensuring high utilization rates and commercial viability requires careful charger siting. Charging infrastructure planning must account for freight demand patterns, land availability, operational characteristics, existing electrical infrastructure, and regulatory requirements.

To support this, MP Ensystems has developed an **Electric Vehicle Charging Infrastructure (EVCI) Siting Tool**, which applies multi-criteria spatial analysis using traffic demand, substation capacity, parking availability, land-use constraints, and GIS-based routing information to identify optimal charging locations. This methodology has previously been applied across **32 freight corridors in India**, covering more than 100 km each¹².

For high-density freight clusters such as Kalamboli, a layered planning approach that integrates freight operations, charging demand, land use, and grid infrastructure can help identify charging locations that minimize grid impacts while maximizing charger utilization and operational efficiency. The illustrated in Figure 5 mentions the layers that can be superimposed to identify optimal locations.

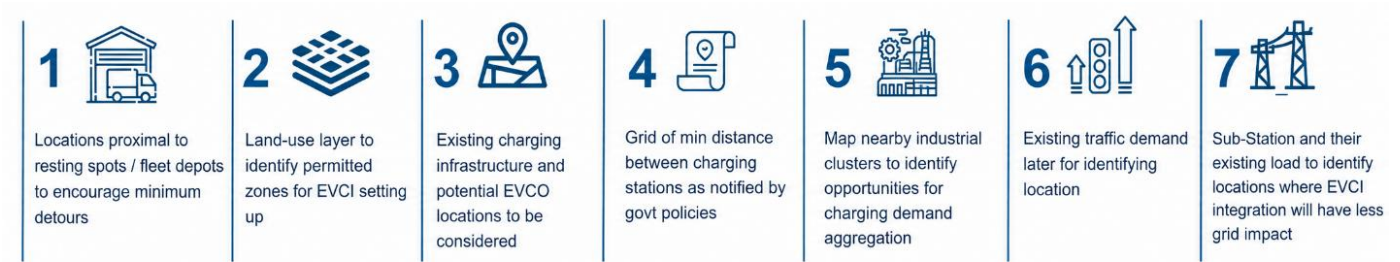


Figure 4.2: Different layers of contextual information to be considered for developing efficient charger siting strategies.

¹¹ MP Ensystems, 2024. [Smart charging in India: Study on EV freight corridor and grid infrastructure for managed charging integration.](#)
¹² MP Ensystems, 2022. [Electric Vehicle Charging Infrastructure Siting Study to Support Freight Electrification.](#)

Recommendations for the Way Forward

1. **Demand aggregation:** Aggregating a baseline demand of 2164 heavy-duty trucks across the Kalamboli and JNPT corridors establishes a predictable scale for phased ZET deployment, creating a concentrated volume that guarantees high utilisation of charging infrastructure, de-risks capital investments and accelerates the rollout of megawatt-scale charging infrastructure.
2. **Grid integration planning:** Our analysis shows that 100% electrification of the Kalamboli truck fleet could add up to 55 MW of additional load to the grid under an overnight charging scenario. Therefore, charging hubs should be strategically sited based on the available capacity of nearby substations to minimize grid stress and infrastructure upgrades. Beyond siting, identifying operationally feasible opportunities to shift charging away from peak periods can further reduce stress on the grid. In Kalamboli, partial shifting of charging demand to morning and daytime hours reduced sanctioned load by nearly 50%. Thus, as freight electrification gathers pace, EVCI planning must go hand in hand with grid planning. This calls for detailed ground-driven studies for grid integration planning and charging strategy development to build a resilient and cost-effective charging ecosystem.
3. **Policy support:**
 - **Targeted policies to support grid integration studies:** Grid integration is a critical aspect of informed EVCI deployment for ZETs, given their significantly higher energy demand. This underscores the need for dedicated policies supporting EVCI grid integration studies and pilot projects. Alternatively, a portion of existing EVCI deployment funding could be earmarked for such initiatives to ensure charging infrastructure expansion remains both grid-ready and scalable.
 - **Targeted cluster/ corridor level charging policies de-risk infrastructure investments:** Policymakers should prioritize incentives for high-density logistics nodes to aggregate freight demand, thereby creating the predictable energy loads needed to attract major private capital for centralized EVCI.
 - **Regulatory frameworks must support smart scaling and grid stability:** State and central policies should incentivize phased infrastructure rollouts and time-of-use (ToU) charging tariffs, enabling fleet operators to achieve a competitive TCO while shielding the broader grid from unmanageable peak loads.

How can you accelerate your decarbonization journey?

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Smart Freight Centre (SFC) is a globally active non-profit organization for climate action in the freight sector. Our goal is to mobilize the global logistics ecosystem, in particular our members and partners, in tracking and reducing its greenhouse gas emissions. We accelerate the reduction of logistics emissions to achieve a zero-emission global logistics sector by 2050 or earlier, consistent with 1.5° pathways.

MP Ensystems Advisory Private Limited established in 2012, is a thesis-driven private consulting firm that actively supports equitable energy and resource efficiency initiatives. The firm's core expertise lies in the energy and environmental sectors, including electricity regulations, clean energy access for development, water resource efficiency and sustainable mobility. Our initiatives also encompass climate finance, aimed at catalysing sustainable change. We support sub-national, national, and international programs through policy advisory, business model development, socio-technical modelling, and by testing innovative solutions and services.

Contact

Smart Freight Centre
Keizersgracht 572, 1017 EM, Amsterdam, Netherlands
www.smartfreightcentre.org
info@smartfreightcentre.org