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Article

Revolutionizing logistics: the road to electrifying goods transport vehicles in India

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Abstract: The electrification of goods transport vehicles has emerged as a crucial solution for the environmental and economic issues associated with traditional transportation systems. Progress in battery technology has significantly improved the feasibility of electrifying goods transport vehicles. Nonetheless, there are notable challenges that need to be addressed, including limited charging infrastructure, limited range, and high upfront costs, which serve as significant barriers to widespread electrification adoption in India. This paper provides a comprehensive overview of the status of electrification in goods transport vehicles, emphasizing the environmental benefits, technological advancements, existing challenges, and possible solutions in the Indian Heavy Commercial Vehicle (HCV) segment.

1. Introduction to good transport sector growth in India

The electrification of transportation is essential for reducing greenhouse gas emissions and addressing air quality concerns. According to the Centre for Study of Science, Technology and Policy (CSTEP), approximately 70% of goods in India are transported via roads [1], predominantly using large vehicles that depend on fossil fuels. More than 32% of trucks in India fall under the category of Medium and Heavy-Duty vehicles, responsible for managing 97% of the nation's freight demand, as illustrated in Figure 1. The Indian trucking industry is the sixth largest market in the world, with more than 5 million registered vehicles accounting for 2% of all vehicles. India currently has an extensive fleet of over 2.8 million trucks that collectively travel more than 100 billion kilometers annually. The road logistics market in India is poised to expand at a Compound Annual Growth Rate (CAGR) of 8% over the next three years, reaching a staggering $330 billion by 2025.

The challenge is how the freight and energy ecosystem can achieve this goal. Truck electrification can only succeed if we expand renewable energy generation and grid infrastructure capacity. Engaging with the four key players shown in Figure 2 presents an opportunity to electrify the entire portfolio. The trucking industry is experiencing significant growth, driven by advancements in communication, increased

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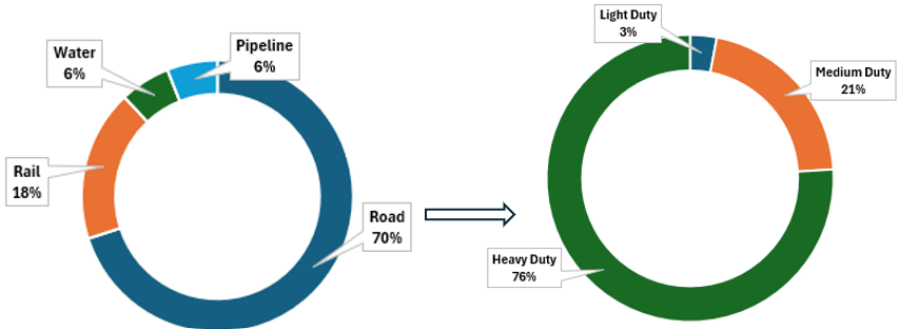

Figure 1. Indian Freight Logistics Segmentation by Mode.

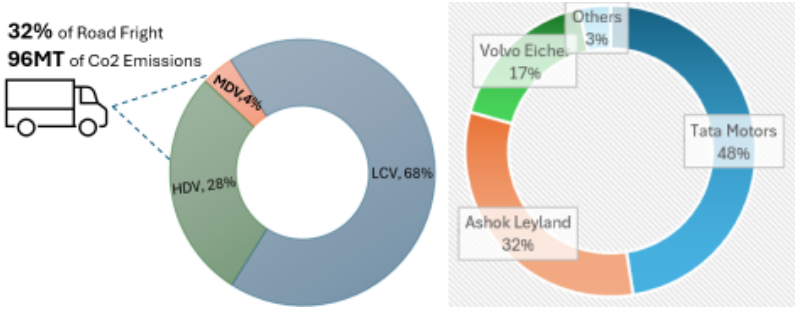

Figure 2. Indian Medium and Heavy-duty Truck Share.

supply and demand, and greater integration of technology. Furthermore, as e-commerce continues to gain popularity, this percentage is projected to rise further, exacerbating the environmental impact of the road freight industry.

As shown in Figure 3, India currently has an extensive fleet of over 2.8 million trucks that collectively travel more than 100 billion kilometers annually. The transport sector in India accounted for 14% of the country's CO2 emissions in 2020, with road freight [2] contributing 90% of this total. The truck sector is energy-intensive and disproportionately pollutes. Although trucks constitute only 2% of the total volume of road vehicles, they are responsible for over 45% of road transport emissions and 35% of on-road fuel consumption. The truck segment contributes a significant amount of tailpipe emissions (CO2 and NOx) due to its high annual fuel consumption and the tonnage of goods moved.

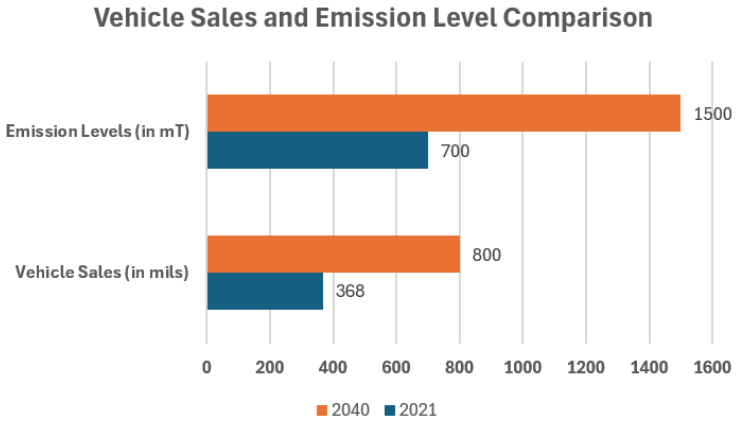

Figure 3. Vehicle Sales and Emission Level Comparison.

Different fuel options like CNG/LNG, biofuels, hydrogen, and others will vie for dominance, influencing the rate at which electric vehicles (EVs) are embraced. The overall emissions from electric Medium and Heavy-Duty Trucks (e-MHDT) will decline as renewable energy becomes more prevalent [3] in the grid. However, it is crucial to address the environmental impact of trucking in India, considering the pollution generated by trucks on highways and their substantial contribution to the country's logistics sector [4]. To achieve a greener trucking system, it is imperative to explore measures that can significantly reduce the environmental footprint of this sector. This heavy dependence on traditional fuel sources contributes significantly to the country's carbon emissions [5].

2. Benefits of Electrifying Goods Transport Vehicles

While the upfront costs of electric vehicles remain a challenge, the operational and maintenance costs of EVs are substantially lower than those of diesel vehicles. This cost competitiveness, coupled with potential government incentives and subsidies, makes the case for electrification economically viable for fleet operators in India. Electrifying goods transport vehicles offers several advantages that can contribute to a sustainable logistics sector in India [6]. Firstly, the adoption of electric vehicles (EVs) reduces greenhouse gas emissions, as they produce zero tailpipe emissions, which mitigates air pollution and helps combat climate change. Secondly, EVs are quieter compared to diesel trucks, thereby reducing noise pollution [7] in urban areas.

Furthermore, electrification presents opportunities for cost savings, as EVs have lower operating and maintenance costs. Additionally, electric drivetrains offer enhanced energy efficiency and improved operational performance, resulting in increased productivity and reduced fuel consumption. Several studies have underscored the potential benefits of electrifying goods transport vehicles in India. For instance, a study by the Council on Energy, Environment, and Water [8] estimates that the widespread adoption of electric trucks and vans in India's urban freight sector could lead to a 31% reduction in oil imports and an 18% reduction in CO emissions by 2030 compared to a business-as-usual scenario [9]. In India, there are only a few EV truck manufacturers [10], and the details of their models are given below in Table 1.

Table 1. E-Truck OEMs in India and Specification.

Segment	Battery Capacity (kWh)	Range (km)	GVW (tonnes)
OEM1 (Medium Duty)	62.5	100	8.7
OEM2 (Medium Duty)	201.5	350	11.9
OEM3 (Heavy Duty)	258	185	55
OEM4 (Heavy Duty)	300	150	28
OEM5 (Medium Duty)	96.77	180	5.5

3. Challenges & Opportunities in Electrification of Truck Segment

However, the electrification of goods transport vehicles in India is not without its challenges. The lack of a well-developed charging infrastructure network is a significant hurdle, particularly for long-haul and intercity transportation. Additionally, issues related to range anxiety, limited battery technology options suitable for heavy-duty applications [11], and the need for supportive policies and regulations require careful consideration. These challenges can be overcome through technological advancements, policy interventions, and collaboration among stakeholders.

Recent studies [12] indicate that electric trucks must comprise approximately 8% of all freight trucks by 2070 to achieve net-zero emissions. This highlights the importance of transitioning to electric vehicles as a viable solution. By adopting electric trucks, industry can mitigate the detrimental effects of greenhouse gas

emissions and contribute to a cleaner and more sustainable transportation ecosystem [13]. It necessitates a comprehensive approach that involves embracing innovative technologies, enhancing infrastructure for electric vehicles, and promoting sustainable practices throughout the logistics sector. By prioritizing greener alternatives and implementing effective policies, the trucking industry can make significant strides toward achieving a more environmentally friendly and efficient future [14].

As outlined in [15], trucks are expected to maintain a prominent position in terms of energy consumption and CO2 emissions within the freight sector. Figure 3 illustrates that the demand for freight services is projected to increase significantly, expanding by a factor of five from approximately 2,000 billion tonne-kilometers (tkm) in 2020 to over 10,000 billion tkm by 2050. Trucks will continue to dominate both energy consumption and CO2 emissions in this sector. According to Figure 4, heavy commercial vehicles (HCVs) currently hold a modal share of more than 60%, with demand [15] predicted to increase fivefold by 2050. The ongoing improvement of road infrastructure, supported by increasing government investments, is expected to sustain strong demand for HCVs in the future.

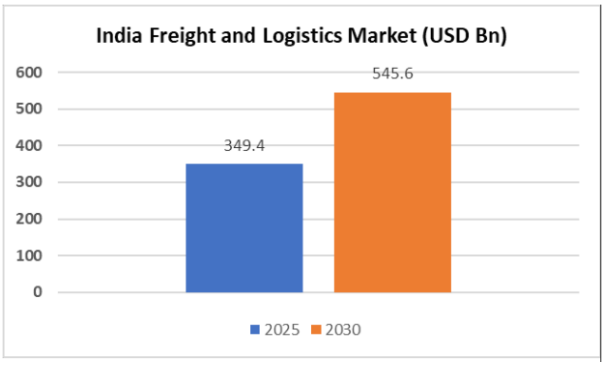

Figure 4. India Freight and logistics Market.

E-commerce logistics solutions are indispensable for any business, encompassing the planning, coordination, and management of goods and services movement. In today's global economy, efficient logistics operations are crucial for maintaining competitiveness and meeting customer demand. Two common logistics service options include Partial Truckload (PTL) and Full Truckload (FTL). PTL handles shipments that do not require an entire truck, whereas FTL manages shipments requiring the full capacity of a truck. These options are essential for optimizing transportation costs, improving delivery times, and effectively managing inventory. A key parameter crucial for quantifying the benefits of electric vehicles is the Total Cost of Ownership (TCO).

Case Study – TCO Comparison of OEM Model (12 Tonn) (Diesel Vs BEV)

To estimate the Total Cost of Ownership (TCO) of MCV/HCV trucks, it is essential to establish baseline mileage data among the major OEMs. Figure 5 presents data collected from 166 truck OEMs in India regarding mileage as per certification. Analysis of the data indicates an average mileage ranging from 4.5 to 5.5 kilometers per liter of fuel.

In this study, Operating and Maintenance Costs are discussed in detail, as they are crucial commercial factors. These day-to-day expenses are particularly significant for fleet owners in maintaining optimal vehicle performance to meet business needs. Table 2 below compares the operating and maintenance costs between a Diesel truck and a Battery Electric Truck (BET). The study focuses on a typical fleet segment covering approximately 9,000 kilometers per day or 108,000 kilometers per year. For the ICE Diesel truck, the assumed mileage is 4.5 kilometers per liter, adjusted from certification to real-world values, with fuel priced at INR 94 per liter at a specific point in time.

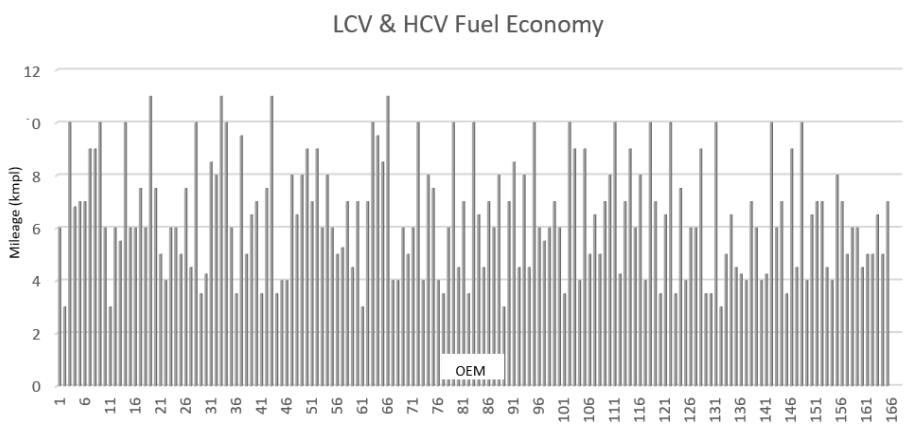

Figure 5. Truck OEMs in India & fuel efficiency.

To estimate the overall operational cost, the fuel cost per kilometer is calculated first using the aforementioned parameters. For instance, for the diesel truck, INR 94 per liter divided by 4.5 kilometers per liter results in INR 21 per kilometer (indicated by a negative sign indicating cash outflow). Multiplying this by 108,000 kilometers gives the total fuel cost incurred annually. Annual Maintenance Cost (AMC) is another essential factor aside from fuel cost, which is incurred yearly and paid to service dealerships. This includes identifying replacement parts, their costs, labor costs, insurance, and average toll expenses over the vehicle's typical ten-year lifespan. Based on this data, AMC for Diesel is estimated at INR 25 per kilometer.

Table 2. TCO Calculation for Diesel Truck and BET – Fleet.

ICE (Diesel)	Unit	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
On-Road Price	Rs	-38,00,000										
Annual Usage	Km		1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000
Expected Mileage	kmpl		5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Fuel Price	Rs		94	94	94	94	94	94	94	94	94	94
Fuel price per km	Rs/km		-17.7	-17.7	-17.7	-17.7	-17.7	-17.7	-17.7	-17.7	-17.7	-17.7
Fuel (Rs. 14.6 / km)	Rs		-19,15,472	-19,15,472	-19,15,472	-19,15,472	-19,15,472	-19,15,472	-19,15,472	-19,15,472	-19,15,472	-19,15,472
AMC (Rs.34/Km)	Rs		-3672000	-3672000	-3672000	-3672000	-3672000	-3672000	-3672000	-3672000	-3672000	-3672000
Total Cashflow	Rs	-38,00,000	-55,87,472	-55,87,472	-55,87,472	-55,87,472	-55,87,472	-55,87,472	-55,87,472	-55,87,472	-55,87,472	-55,87,472
Cumulative Cashflow	Rs	-38,00,000	-93,87,472	-1,49,74,943	-2,05,62,415	-2,61,49,887	-3,17,37,358	-3,73,24,830	-4,29,12,302	-4,84,99,774	-5,40,87,245	-5,96,74,717
BEV												
On-Road Price	Rs	-53,20,000										
Annual Usage	Km		1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000	1,08,000
Expected Mileage	kmpl		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Energy Cost	Rs		-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
Range	km		185	185	185	185	185	185	185	185	185	185
Battery Capacity	kWh		258	258	258	258	258	258	258	258	258	258
Energy cost per charging	Rs		-2,064	-2,064	-2,064	-2,064	-2,064	-2,064	-2,064	-2,064	-2,064	-2,064
Energy Cost per km	Rs		-11.2	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2
Fuel (Rs.11.2 / Km)	Rs		-12,04,930	-12,04,930	-12,04,930	-12,04,930	-12,04,930	-12,04,930	-12,04,930	-12,04,930	-12,04,930	-12,04,930
AMC (Rs.17/Km)	Rs		-18,36,000	-18,36,000	-18,36,000	-18,36,000	-18,36,000	-18,36,000	-18,36,000	-18,36,000	-18,36,000	-18,36,000
Total Cashflow	Rs	-53,20,000	-30,40,930	-30,40,930	-30,40,930	-30,40,930	-30,40,930	-30,40,930	-30,40,930	-30,40,930	-30,40,930	-30,40,930
Cumulative Cashflow	Rs	-53,20,000	-83,60,930	-1,14,01,859	-1,44,42,789	-1,74,83,719	-2,05,24,649	-2,35,65,578	-2,66,06,508	-2,96,47,438	-3,26,88,368	-3,57,29,297

For Battery Electric Trucks (BETs), Total Cost of Ownership (TCO) includes additional parameters and is calculated differently compared to Diesel trucks. For instance, consider a vehicle with a battery capacity of 258 kWh and an estimated range of 185 kilometers per single charge. The TCO calculation for BETs factors in energy costs, assuming private or depot charging at INR 8 per kWh. The effective range of an EV depends on usable battery capacity (Wh) and energy consumption (Wh/km). Based on data from available models in India, estimated energy consumption ranges from 0.8 to 1 kWh per kilometer. In this study, a baseline of 0.9 kWh/km is assumed for TCO estimation. Thus, the EV fuel cost (energy cost) is calculated as INR 11.2 per kilometer.

Annual maintenance costs for EVs are lower compared to ICE vehicles due to the absence of many engine components and fluids that require regular servicing and replacement over the vehicle's lifespan. Key components requiring servicing include the battery, electric motor, and charging ports (if applicable). Modern EVs often feature regenerative braking, where the electric motor acts as a generator during braking, sending electricity back to the battery pack. This system improves braking efficiency, reduces wear and tear on traditional brake pads, and minimizes brake dust emissions, contributing to cleaner air quality. Thus, while brake pads may still require periodic replacement, their service life is typically extended in EVs.

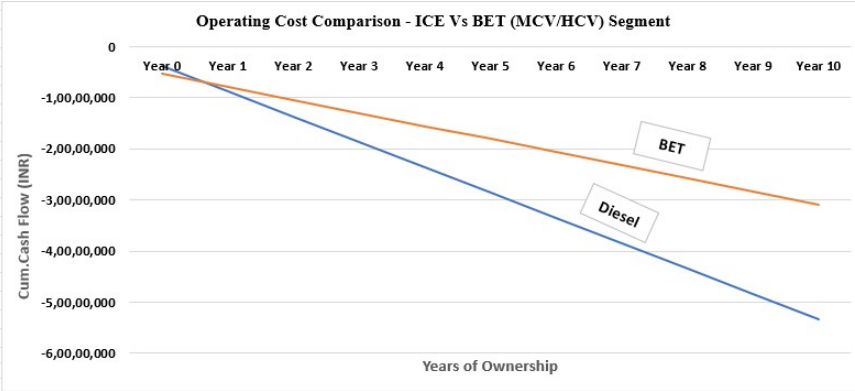

Figure 6. Operating Cost Comparison – Diesel Truck (ICE) Vs BET.

Based on this data, the Annual Maintenance Cost (AMC) for the Battery Electric Truck (BET) is estimated at INR 12.5 per kilometer, which is 50% lower than the AMC for a typical diesel truck. The results indicate that BETs are cheaper in terms of both running and maintenance costs, leading to an earlier breakeven point for EVs compared to ICE models, as illustrated in Figure 6.

4. Future State & Role of Renewable Energy Sources for Energy

The upfront costs of electric vehicles remain a challenge; however, the operational and maintenance costs of EVs are significantly lower than those of diesel vehicles. This cost competitiveness, along with potential government incentives and subsidies, makes the case for electrification economically viable for fleet operators in India [16]. Electrifying goods transport vehicles offers several advantages that can contribute to a sustainable logistics sector in India. Firstly, the adoption of electric vehicles (EVs) reduces greenhouse gas emissions since they produce zero tailpipe emissions [17]. This helps mitigate air pollution and combat climate change. Secondly, EVs are quieter compared to diesel trucks, thereby reducing noise

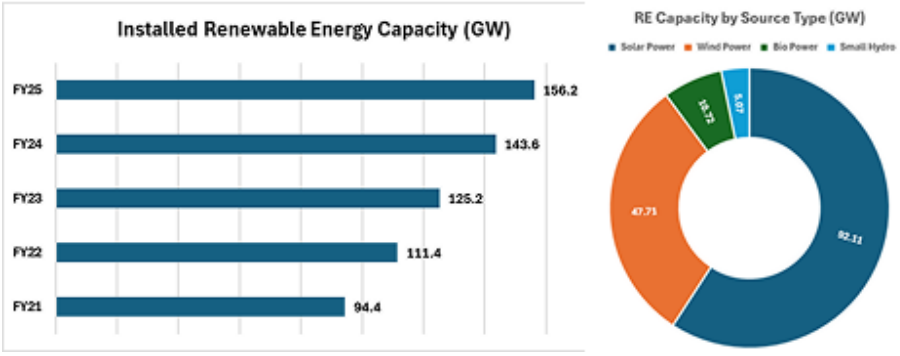

Figure 7. India's Renewable Energy Installed Capacity Source.

pollution in urban areas. Furthermore, electrification presents opportunities for cost savings, as EVs have lower operating and maintenance costs. Additionally, electric drivetrains offer enhanced energy efficiency and improved operational performance, resulting in increased productivity and reduced fuel consumption.

The challenge lies in meeting the energy demand, as India is projected to require about 100 terawatt-hours (TWh) of electricity by 2030, equivalent to approximately 5% of the total electricity generation. Several studies highlight the potential benefits of electrifying goods transport vehicles in India [18]. For example, a study by the Council on Energy, Environment, and Water suggests that widespread adoption of electric trucks and vans in India's urban freight sector could lead to a 31% reduction in oil imports and an 18% reduction in CO2 emissions by 2030, compared to business-as-usual scenarios [9].

Traditional approaches to powering EV charging stations often rely on electricity generated from fossil fuels, thereby perpetuating carbon emissions [19]. Renewable energy sources such as solar, wind, hydroelectric, and biomass offer a sustainable alternative for powering EV charging infrastructure. This section examines the advantages of renewable energy in reducing fossil fuel dependency, including environmental benefits, energy security, and cost-effectiveness, as illustrated in Figure 7. Effective integration of renewable energy into EV charging infrastructure requires careful planning and implementation.

To achieve the electrification of freight vehicles, the following concepts could be explored:

a) Standardized Battery Selection for Truck Manufacturers

The batteries for the truck segment could be standardized with respect to size, capacity, warranty, etc., with more than one option for manufacturers to choose from. Once the batteries are standardized, customers could choose to buy or lease batteries from outside vendors. Leasing the battery could cost less than owning one, resulting in a cost benefit for the customer. Also, since batteries could be standardized, manufacturers need not include the battery in the Bill of Materials, which has the potential to reduce the overall cost of the vehicle.

b) Reducing Range Anxiety with Battery Swap Options

Assuming that the batteries are standardized, the option to either charge the existing battery depending on time availability or swap it [20] with an already charged battery could be done at authorized battery charging/swapping stations. This could considerably reduce charging times and alleviate range anxiety [11] for customers. Battery swapping helps in minimizing battery degradation, eliminating charging times, and enhancing operational efficiency.

c) Management through Mobile Applications

As the above concepts are strengthened and with the aid of connected technology, options to pre-order batteries, check battery health, know the wait time at battery stations, etc., could be added to benefit the customer. Data analytics to study driver behavior and battery usage patterns could help manufacturers understand real driving conditions better, enabling them to make improvements.

5. Strategies of Using Renewable Energy for BET Charging Systems

Integration strategies for renewable energy into electric vehicle (EV) charging infrastructure involve various approaches to optimize the use of renewable energy sources while ensuring reliable and efficient charging services. Figure 8 shows the interaction between energy management and their respective strategies.

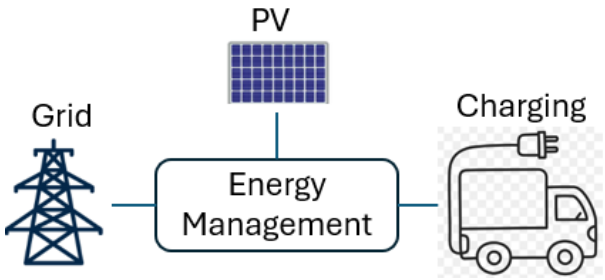

Figure 8. Integration strategies for renewable energy.

5.1. Grid-Connected Systems

The setup comprises an energy source (PV) and energy storage (battery), interconnected with the power grid. Electric vehicles (EVs) are charged using renewable power, with battery and grid support as needed. Surplus power is directed to the battery and subsequently to the grid as necessary. This approach [21] enables the smooth incorporation of renewable energy into charging infrastructure, ensuring grid stability and reliability are maintained.

5.2. Standalone Installations

Independent EV charging stations, powered solely by renewable energy, provide a decentralized solution for charging infrastructure. They can be deployed in remote or off-grid areas where connecting to the main grid is impractical or expensive. The Electric Circuit stands as Quebec's largest public charging network for electric vehicles, boasting over 5,000 public charging stations, with nearly 900 of them being fast-charge stations, spread across every region of the province. These stations provide clean and reliable charging services to EV drivers in areas with limited access to the grid, demonstrating the effectiveness of standalone renewable energy installations. The table below summarizes various test cases in which electric trucks can make use of the available time and charging patterns [22] to maximize the available energy at a reasonable cost.

Table 3. Potential test cases for electric fleet charging.

Mode	Description	Available Time	Charging Power	Charging Cost (per kWh)
Truck Depot	Home Depot, Owners Parking bay	8 hours	AC 22 kW DC 150 kW	
Logistics Park	Destination Parking, Material Transfer Idle time	3-4 hours	DC 350 kW	INR 8 to INR 20* (DC Fast charging cost data for more than 20 kW rating is not available in India)
Fast Charging	Lunch break time, Emergency Charging	1 hour	DC 500 kW DC 1 MW	
Public Charging @ Truck Bay	Night time, Break time, long haul, Routine Maintenance	8-10 hours	DC 100W DC 150W	
Swapping	Quick Energy demand to support enroute	5-10 mins	AC 22 kW DC 150 kW	

5.3. Energy Storage Solutions

Energy storage systems, like batteries, play a vital role in complementing renewable energy sources by storing surplus energy for utilization during peak demand or times of low renewable energy production. By integrating energy storage into EV charging infrastructure, grid stability is improved, and there's increased flexibility in managing renewable energy resources. Tesla's Powerpack energy storage system is strategically installed alongside solar carports at EV charging stations, facilitating the storage of excess solar energy. This stored energy can then be utilized for nighttime charging or during peak demand periods, ensuring consistent and reliable EV charging services. By integrating these technologies, renewable energy utilization is optimized, leading to more efficient and sustainable charging infrastructure.

5.4. Smart Charging and Demand Response

Smart charging systems enable demand response in EV charging infrastructure. These systems empower utility companies to regulate the charging of electric vehicles, either remotely or by communicating with the vehicle directly, as shown in Figure 9. By orchestrating charging schedules, utilities can optimize charging times to coincide with periods of reduced electricity demand or increased renewable energy generation, thereby enhancing grid stability and maximizing the utilization of renewable resources. The "Vehicle-to-Grid" (V2G) technology integrates EV batteries into the grid, allowing bidirectional energy flow between vehicles and the electricity network. This enables EVs to serve as mobile energy storage units, supporting grid stability and balancing renewable energy fluctuations.

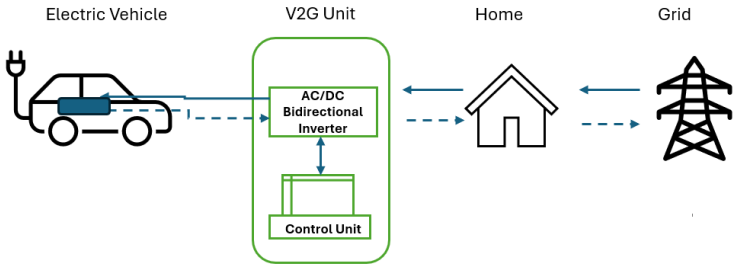

Figure 9. Block diagram of the V2G structure.

5.5. Virtual Power Plant

A Virtual Power Plant (VPP) is a virtual network that integrates various types of distributed energy resources, such as solar panels, batteries, electric vehicles, and wind turbines, through a cloud-based system as is shown in Figure 10. It serves as a platform where power utilities, renewable energy operators, energy producers, retailers, VPP operators, and building managers collaborate.

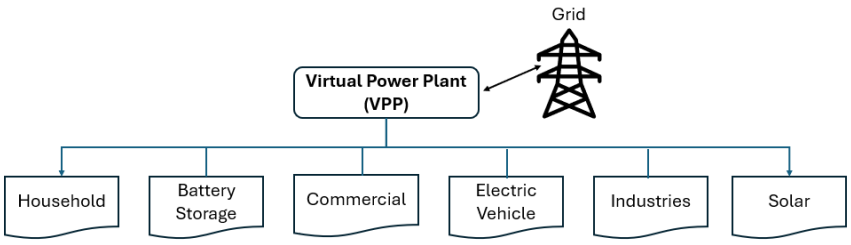

Figure 10. An Example of Virtual Power Plant.

Similar to how internet-connected desktop computers revolutionized computing compared to mainframe computers, a VPP transforms energy management. It can generate power, trade electricity within and between systems, and buy and sell power in the market. Essentially, it's a flexible and dynamic approach to energy production and distribution.

Integration strategies for renewable energy into EV charging infrastructure offer diverse approaches to optimize the use of clean energy sources while meeting the growing demand for electric transportation. By implementing these strategies and leveraging technological innovations, stakeholders can accelerate the transition towards a sustainable and resilient energy system.

Case Study – Renewable Energy-Powered Fleet Electrification of OEM A

Background

OEM A is one of the largest manufacturers of commercial vehicles, including trucks and buses, in India. The company is committed to sustainability and has been exploring ways to integrate renewable energy into its operations to support the electrification of its fleet.

Integration of Renewable Energy

OEM A implements renewable energy solutions to power its fleet electrification efforts.

Solar-Powered Charging Infrastructure

The company collaborates with renewable energy providers to deploy solar-powered charging infrastructure at its manufacturing facilities and distribution centers. These charging stations utilize solar energy to charge electric trucks, reducing carbon emissions and operating costs.

Renewable Energy Procurement

OEM A procures renewable energy from solar and wind power projects through power purchase agreements (PPAs). By sourcing green power [23] from renewable energy developers, the company reduces its carbon footprint [24] and supports the growth of India's renewable energy sector.

Energy-Efficient Manufacturing

OEM A invests in energy-efficient manufacturing processes and facilities to reduce energy consumption and environmental impact. By implementing energy-saving measures and adopting renewable energy technologies, the company minimizes its carbon emissions throughout the production lifecycle of its trucks. The benefits are given below.

Environmental Sustainability

By utilizing solar power and other renewable energy sources, the company reduces the environmental footprint of its truck fleet. This aligns with the company's commitment to sustainability and helps mitigate climate change by reducing greenhouse gas emissions.

Cost Savings

Solar-powered charging infrastructure and renewable energy procurement offer cost savings compared to traditional fossil fuel-based energy sources. The company benefits from lower operational expenses and increased energy independence by leveraging renewable energy solutions.

Brand Leadership

Adoption of renewable energy and support for fleet electrification position the company as a leader in sustainable transportation in India. By promoting clean energy adoption and driving innovation in the truck industry, the company enhances its brand reputation and competitiveness.

Conclusion

OEM A's integration of renewable energy into its fleet electrification strategy demonstrates the company's commitment to sustainability and environmental stewardship. By leveraging solar power and other renewable energy sources, OEM A contributes to India's efforts to transition towards a cleaner and more sustainable transportation system.

6. Initiatives and Pilot Projects

India has witnessed various initiatives and pilot projects aimed at electrifying goods transport vehicles. These projects have explored innovative solutions and provided valuable insights into the feasibility and benefits of EV adoption. Moreover, collaborations between public and private entities, along with supportive government policies [25], have accelerated the deployment of EVs in logistics operations. India's flagship scheme, Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME) II, offers incentives worth approximately Rs 20,000 per kWh. To boost electric mobility and promote the development of electric vehicles, a phased manufacturing roadmap (PMP) has been developed. This roadmap aims to promote the indigenous manufacturing of electric vehicles, their assemblies/sub-assemblies, and parts/sub-parts/inputs of the sub-assemblies over time through a graded duty structure.

The Basic Customs Duty (BCD) on Semi Knockdown Units (SKD) Trucks has increased to 25% from an earlier BCD of 15%. BCD on Li-Ion cells and other parts has also increased by 10% and 15%, respectively. Goods & Services Tax (GST) on electric vehicles has been reduced from 12% to 5%, while GST on chargers/charging stations has been reduced from 18% to 5%. The Ministry of Road Transport & Highways (MoRTH) announced that EV goods carriers will be exempt from permit requirements for carrying goods. These initiatives serve as valuable models for scaling up electrification efforts and overcoming implementation challenges.

The government offers various financial incentives to make electric vehicles more affordable. The key mechanisms for obtaining these incentives include:

1. **Purchase Incentives:** Direct discounts on the cost of the electric vehicle [26].
2. **Coupons:** Financial incentives reimbursed to the buyer later.
3. **Interest Subventions:** Discounts on interest rates for loans taken to purchase electric vehicles.
4. **Road Tax Exemption:** Waiver of road tax at the time of purchase.
5. **Registration Fee Exemption:** Waiver of the one-time registration fee for new vehicle purchases.
6. **Income Tax Benefit:** Deductions on the tax amount payable by an individual.
7. **Scrapping Incentives:** Provided for de-registering old petrol and diesel vehicles.
8. **Other Incentives:** Including interest-free loans, top-up subsidies, and special incentives for electric three-wheelers.

Policy should include special measures for charging infrastructure, such as offering discounted land and lower charging rates. Additionally, building charging stations in key freight areas [27] along busy routes can improve efficiency and range for e-trucks. Policies should also gradually adopt stricter efficiency and emissions standards to encourage manufacturers to produce zero-emission trucks (ZET).

7. Conclusions and Future Work

Electrifying trucks can accomplish several policy objectives, including decreasing oil imports, reducing air pollution and greenhouse gas emissions, and lowering the cost of freight transportation. Although the electrification of light-duty vehicles and buses has already begun, truck electrification presents unique challenges. Freight trucks face harsher environmental conditions and tougher duty cycles compared to buses and light-duty vehicles. Additionally, trucks must maintain payload capacity to generate revenue, which limits the weight and volume of battery packs. Trucks also require faster charging capacities, which increase thermal stress on batteries and shorten battery life. Due to these challenges, Battery Electric Trucks (BET) will need to undergo extensive experimentation in design, manufacturing, and deployment of different battery chemistries, pack designs, and charging cycles.

Electrifying freight transport vehicles in India would require a systematic segregation of transport systems, such as intercity, intracity, and state-to-state. This segregation will enable a clearer view of the broader picture in addressing transport requirements and provide better solutions. Addressing the two major issues—cost of EV batteries and charging time—would significantly improve the usage of EV vehicles. The charging time and frequency of vehicles in intercity and intracity settings will differ significantly from those traveling between states. Given the strong demand for Heavy Commercial Vehicles (HCVs) and their impact on inflation, there is a compelling reason to study, analyze, and investigate opportunities to electrify HCVs. The ecosystem would include battery swapping, fast charge stations, and possible solutions to improve battery charging time and frequency.

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