International Journal of Creative and Open Research in Engineering and Management
ISSN: **3108-1754 (Online)**
Volume 02 Issue 03 March-2026 | Impact Factor: 3.5

The Evolution and Future of Electric Vehicle Charging Infrastructure in India: A Comprehensive Review

Anuj Verma[1], Akshit Ramteke[2], Anushka Jadhao[3], Anushka Andraskar[4], Aniket Dhanke[5]

[1] Electrical Engineering / Government College of Engineering / Nagpur, India
see15kkv@gmail.com[1]
[2] Electrical Engineering / Government College of Engineering / Nagpur, India
akshit169.bcr@gmail.com[2]
[3] Electrical Engineering / Government College of Engineering / Nagpur, India
anushkajadhao70@gmail.com[3]
[4] Electrical Engineering / Government College of Engineering / Nagpur, India
anushkaandraskar88@gmail.com[4]
[5] Electrical Engineering / Government College of Engineering / Nagpur, India
aniketdhanke19@gmail.com[5]

How to Cite this Article:

Verma, A., Ramteke, A., Jadhao, A., Andraskar, A. & Dhanke, A. (2026). The Evolution And Future of Electric Vehicle Charging Infrastructure in India: A Comprehensive Review. International Journal of Creative and Open Research in Engineering and Management, 02(03). https://doi.org/10.55041/ijcope.v2i3.044

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Abstract—

On India's streets, the shift shows best where silent rides now cut through old rumbles. Power spots guide this turn - opening doors while also slowing steps. At first, FAME-I helped people buy clean cars, but soon gear lagged behind demand. So FAME-II stepped in, pushing stations over sedans. Lately, wires took their cue from PM E-DRIVE, turning attention once more.

By February 2026, India counted more than 29,151 public EV charging stations. Money flowed in - over two thousand crore rupees through PM E-DRIVE, on top of earlier backing past six hundred thirty-three crore under FAME-II. Rules lightened that year when the power ministry dropped licensing needs for charger setups. With softer guidelines from MoP's 2024 revision, private firms faced fewer hurdles.

Quick shifts in technology favor DC setups such as DC001 and CCS instead of standard AC charging. On smaller machines, battery exchange hubs are showing up, opening a different route entirely. With V2G techniques, energy moves back and forth between autos and the grid, smoothing out demand peaks. Still, tying these pieces together within current electrical networks creates complications. Though improvements exist, steep initial prices keep plenty of customers away. Space for charging stations in busy urban areas is tight - that pressure only grows. Regulations plus costs, along with where you can build, continue holding progress back.

The NITI Aayog 2025 report claims India's electric vehicle market might reach 200 billion dollars by 2030. Hitting that mark likely hinges on rolling out charging points beyond cities, into rural areas. Stations allowing battery swaps using standardised ports could play a role as well. When cars draw electricity matters - using smart systems to time those draws may reduce strain on the grid. Numbers do the talking here, not guesses. What emerges is a picture of where electric vehicle chargers could settle in over time. Shape begins to form when data leads instead of hopes.

Keywords— EV Charging Infrastructure; Electric Mobility India; PM E-DRIVE; Battery Swapping; Vehicle-to-Grid (V2G); Grid Integration

I. INTRODUCTION

Electric transport in India ties closely to healthier skies, reliable power, fewer blackouts, more jobs. Around the globe, cities release nearly 70 percent of heat-trapping emissions - mobility alone drives close to one-third, showing how shifting daily commutes can shift outcomes. Thick haze clouds hang above big Indian hubs, AQI readings routinely climbing past 141, pushing communities toward tailpipe-free options amid growing health concerns.

More cars running on petrol and diesel mean higher fuel imports, making government spending jump whenever worldwide oil rates change [16]. Shifting to electric transport might cut how much families spend filling up, while also reducing repair bills - especially now that solar panels and wind turbines are spreading through India [16].

A steady flow of electricity keeps medical tools running during critical moments. When power drops, machines stop working at the worst times. Knowing what makes charging setups tick reduces surprise breakdowns. It isn't just about cords and outlets - small things shape how well energy moves. Devices stay alive only when their charge source holds up. A single working device needs hidden connections beneath it. When time presses hard, understanding the unseen parts becomes key.

Fear of getting stranded without charge slows electric car use across India. Because of this, the push for strong yet affordable charging spots took center stage in the 2020 mobility plan and later efforts [16], [18].

Fixing just roads and electricity grids won't fix every problem for electric vehicles in India because needs change depending on the vehicle size. Homes and workplaces might work fine for charging small cars or scooters, yet big transport like buses or freight trucks need special stations placed across city routes and major highways. Another path shows up where tiny rides dominate - swapping batteries instead of sitting through charges becomes useful. That option isn't some extra plan - it fits how people already move around and send things from one place to another.

Start deep into how India handles charging stations for electric cars. From 2015 onward, government rules shifted, quietly steering what we see today. Standards? They differ - some fresh, a few reshaped - as real-world use guides progress. Moving toward electric travel touches jobs, expenses, life routines. Much depends on choices already made. Where things head by 2030 ties back to choices right now. Looking at research, plus real-world numbers, reveals what hurdles lie ahead. Good answers show up once proof connects with actual conditions, not ideas alone. Behind every number there's a tale of reach, struggle, or waiting. Look closer. Small things hold what matters most. Anyone checking now might blink twice at how much shifted. Moving forward means matching speed with what's already unfolding. What repeats beneath the surface shows where energy actually flows. Plans fall short, yet life keeps bringing new shapes anyway. Certain steps happen slow, slipping in like morning light through blinds. Some lose momentum even after strong starts. What matters grows clearer through quiet watching, not loud statements. The noise fades, and vision sharpens. Truth hides where most stop looking. Quiet attention finds what louder efforts miss.

II. POLICY EVOLUTION

Nowhere else had seen such a quiet shift like India's capital. Instead of pushing more rebates for buying electric vehicles, attention turned toward what happens after the sale. Charging stations began appearing where they once were missing. A different kind of progress took root - slower, less flashy. Roads started adapting without fanfare. Power networks grew not because of mandates alone but through steady groundwork. What looked like small steps added up beyond city centers. Movement followed function, not just promises.

II.1 FAME-I (2015-2019)

Kicked off in 2015, Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles - known as FAME-I - emerged from NE MMP 2020. Its aim? Jump-starting progress in electric transport. Rather than sit back, the program fueled momentum using monetary incentives. At the point of sale, buyers received financial assistance. Original Equipment Makers jumped in too. Rewards worked like gentle pushes, never guarantees. People who bought first meant more than big numbers at that stage. Help moved in circles - shoppers gave it, companies got it, everyone shared. Although FAME-I gave a push to electric cars at the start, charging spots were mostly overlooked. Its backing did help launch pilot projects that laid down basic tech systems while placing several hundred chargers across big cities [4]. A key takeaway appeared along the way: when charger numbers stall, handing out car subsidies does not go far [1], [6].

II.2 FAME- II (2019-2024)

II.3 PM E-DRIVE (2025-Present):

A change arrived following FAME-II: the Prime Minister's push for electric motion in upgraded vehicles - called PM E-DRIVE - launched under updated guidelines set on September 26, 2025. From towns to remote zones, its focus lands where future EV growth may quietly take root [Web Data].

The plan has a number of significant improvements:

Folks see more cash flowing into projects that matter these days. Not skimping this time, 2,000 crore finds its way strictly to essentials like highways and electricity - a shift from earlier moves. Despite past habits, groundwork now holds priority.

Out past the big cities, the PM E-DRIVE plan turns attention to tiny towns and rural spots. Rather than fixating on metros alone, it drives development into areas with fewer people. The goal? Spreading out how easily folks can reach electric travel options. Power points pop up farther apart, touching zones previously ignored. Because of this, switching to electric rides feels fairer across India. Faraway places now step into the spotlight. Where once only cities led, quiet towns follow close behind. Change spreads uneven ground with steady hands. Even corners forgotten by progress find their turn. Fair access stands firm at the center of it all.

A fresh approach emerges when public goals link with private effort, official funds stepping in to cover shortfalls that could stall momentum. Assistance may come as financial backing or easier terms on property use. From that point forward, authority moves beyond state hands. Firms handle construction, daily operations, system setup, maintenance - each phase of a station's lifespan managed independently. Such transitions reflect deliberate strategies seen in similar frameworks documented earlier [23].

One out of every two rupees from the 2000 crore budget pays for charging stations meant for city buses. Powering over fourteen thousand electric buses becomes possible through these points. Largely, they appear in recently included town zones. Overnight recharging happens at complete depot setups built just for that purpose. Funded projects center on systems used every day for getting around town. Chosen spots depend less on population alone, yet more on how buses actually serve those areas.

A new way of doing things drops solar-powered hubs into far-off spots, running farm gear on clean energy instead of fuel - backed by initial incentives [23].

II.4 OTHER STATE GOVERNMENTS POLICIES

Folks running states like Delhi, Maharashtra, and Karnataka didn't wait around - instead they rolled out local electric vehicle programs of their own. Usually, those come packed with perks such as cash help when buying a new model

Operators running charging stations get land at lower prices through special loan terms [2], [3].

Because electric vehicles skip road taxes and registration fees, more people might start using charge stations. This could bring fresh customers looking to save money.

State money helps pay for EV charging gear through capital grants at the local level.

A turning point came when the Ministry of Power issued guidance on September 17, 2024 - building an electric vehicle charging station didn't need official permission. So long as setups meet standards set by the MoP and the Central Electricity Authority, anyone can put up a public charging spot. Compliance with technical and safety rules remains essential, yet no license blocks the way. This shift opened access without loosening oversight.

III. CURRENT LANDSCAPE (2025-2026)

III.1 STATISTICS AND DEPLOYMENT STATUS

Few months into 2026, signs of progress show up across construction sites. Information pulled straight from reports by the Ministry of Heavy Industries and PIB backs that view

Across the whole population, there are 29,151 electric vehicle charging stations in total [24].

Few thousand charging points sat idle when the ten years started. Then came a sharp climb, catching pace fast. Implementation sprinted ahead, especially once FAME-II neared its end. Momentum held into the early days of PM E-DRIVE. Numbers tell that story - quiet at first, then sudden surge.

City hubs hold most stations, yet busy road routes like Delhi to Chandigarh or Mumbai toward Pune also host them [2], [24].

III.2 MARKET STRUCTURE AND KEY PLAYERS

Indian EV charging market is a combination of both public and private:

Out front, some government-linked groups like Energy Efficiency Services Limited are pushing ahead with bulk buying and setting up electric vehicles plus their chargers. Not far behind, public oil firms - think IOCL, BPCL, HPCL - have jumped into big-time installations too. Instead of bundling everything together, EESL split its requests: one batch for thousands of EVs, another just for charging spots nearby. These moves show a shift happening quietly but steadily across state-driven projects.

One thing about city charging spots is how firms like Tata Power show up there a lot. Charging stations at malls often link to services run by Statiq. Home setups sometimes come from Magenta Power instead. Destination points get attention through these names quite regularly. Large scale work now falls into place mainly because of such groups pushing forward quietly. Each one handles different spaces without making too much noise.

One reason folks like aggregators? They link up various charging networks into a single hub. Picture hopping between power spots without hassle - this setup makes it smooth. Different providers become reachable through just one interface. Problems finding stations fade when these systems team up. Their role matters because navigation gets simpler across scattered options [1].

III.3 BUSINESS MODELS AND MARKET DYNAMICS

Service-focused setups now shape how markets operate. What once centered on goods has shifted slowly. New patterns replace old ways without force. Ways of connecting buyers and sellers evolve quietly. Focus moves toward support, access, guidance - less about ownership. This shift does not shout; it settles in. Old habits fade while new ones take root beneath the surface

Out on city streets and highways, you'll find most public chargers set up where delivery vans stop or drivers go far

between stops. These spots make money not just from power sold but also through extras like coffee shops or small markets built right into the charging area [2], [8].

Captive Charging means dedicated charging spots built just for specific groups of vehicles - like delivery vans or city buses - that run almost nonstop every day. These setups serve companies such as Amazon or Flipkart, where electric fleets return to fixed hubs nightly. Instead of public networks, they rely on private infrastructure tailored to tight schedules. High usage makes constant downtime impractical, so charging fits naturally into rest periods. Buses often plug in during short breaks between trips. This approach skips long waits by syncing power-up times with routine stops. Efficiency comes not from speed alone but timing aligned with daily routes.

A fee each month keeps things running - common among businesses using two-wheel vehicles - with either unlimited access or lower costs built in [7].

IV. TECHNICAL ADVANCEMENTS

The technical environment of EV charging in India is marked by the shift towards high-power, smart, and bidirectional systems and outdated ones.

IV.1 AC VS DC TECHNICAL SPECIFICATIONS CHARGING STANDARDS

A different kind of market shows up in India, where most electric vehicles are scooters or small trucks. That reality pushes standards down two separate paths - low power and high power setups must both fit local needs. One path doesn't work alone when wheels and demand split so sharply.

Standardizing Alternating Current

A lone figure in the world of chargers, the AC001 stands apart - crafted by India's Department of Heavy Industry with local needs in mind. Though modest, it pushes out 3.3 kW using 15 amps across 230 volts AC [17]. Found commonly where people live and labor, it slips neatly into familiar 15-amp outlets already on walls. Its design leans on what's already there, making adoption quiet, almost unnoticed.

A basic charging unit, Type-I (AC001) delivers 3.3 kW of power steadily. While it isn't fast, it fits everyday needs without complexity. Its design stays simple on purpose - nothing flashy, just consistent performance.

Higher-power AC charging shows up in Type-II units, often pushing past 3.3 kW - sometimes hitting 22 kW. Found across office spaces and housing blocks, these stations power up four-wheeled EVs without fuss. The Mennekes plug gives it wide reach, fitting many current electric models. Standardized design means fewer headaches when plugging in.

DC Fast Charging Standards

Fast charging at 48 V or 72 V - that's what DC001 offers, known also as BEVC-DC001. This setup pushes out either 10 kW or 15 kW of power [17]. Not seen elsewhere quite like India, it runs on lower voltage but charges quickly. Electric rickshaws plus delivery scooters benefit most because they spend less time waiting. Speed matters when trips add up each day.

Starting off, CCS Type-2 sets the benchmark for high-voltage DC fast charging across India - anything above 150 volts direct current counts. While built for speed, it handles everything from city electric buses to premium cars, delivering power that ranges between 50 kilowatts and beyond 350 kilowatts [2], [17]. Instead of separate ports, this version packs alternating and direct current pins into a single plug design, opening doors to broader compatibility. Flexibility peaks here because one connection manages multiple charging types without switching gear.

Now things stand different. India's leaders and companies agreed on CCS for strong electric flows, yet picked DC001 where power runs weaker, even though global models once guided first trials [17].

IV.2 RAPID CHARGING AND SOPHISTICATED POWER ELECTRONICS

A twist nobody saw coming - faster charging depends entirely on what happens inside next-gen power systems. Over in India, researchers alongside startups push forward: chasing quick top-ups without wrecking battery life.

Jumping straight in, efficiency gets a boost from resonant converters. Where space is tight - like cities - smaller setups make sense. Dense engineering lets high power live in tiny spots. Charging hubs in towns use less ground but deliver just the same. Clear evidence backs these gains, as one source shows [20].

Fresh from labs, some chargers swap standard silicon for tougher mixes such as silicon carbide or gallium nitride. When things get hot, these keep working smoothly while moving higher power loads. Less juice gets lost during the jump, so they stay sharp even when stressed [20].

Faster charging sends heat racing through cars and their power units. That is why roadside recharge points along heavily used paths are trying out strong cooling methods. Near highways such as the one linking Mumbai and Ahmedabad, certain hubs operate well beyond 150 kW – some reaching 400 kW - with liquid-driven thermal control. Such systems keep things stable while energy surges in quickly. Testing spreads further across key transit corridors everywhere.

IV.3 SWAPPING BATTERIES: ECHNOLOGICAL AND BUSINESS DEVELOPMENT

Swapping batteries now competes with refueling diesel trucks, especially where constant operation matters more than parked charging. Design choices center on how systems handle:

Out of time? Swap your empty power pack at one of those lockers - fully or partly automatic - for a fresh one. Takes less than 120 seconds flat [2], [7].

A shared size matters first - mismatched shapes block swaps between makers. Plug styles need matching too; otherwise, connections fail despite good intent. Communication must speak the same language, like CAN-bus signals agreeing on charge levels. One brand's pack should fit another's bike without tweaks. That fit only works if rules exist for all [2], [7].

Weaknesses -

One way companies cut e-bike prices nearly 40 percent? Letting riders pay just for the power they use - charge by charge [2].

Starting off fresh means tracking every battery across the network using smart tools that check how full they are, where they sit, and their general wear. These systems watch closely so charging routines at stations can adapt on the fly. A different rhythm each time helps avoid strain. Life spans stretch out when pulses shift naturally instead of following a fixed path. Details like position and current status feed into smoother decisions behind the scenes [7].

IV.4 VEHICLE TO GRID (V2G) AND SMART CHARGING.

A surge in electric vehicles could strain power systems if charging happens without coordination. Without smart controls, local transformers might fail under heavy load. Power quality often drops when demand spikes unexpectedly. These issues tend to cluster in neighborhoods where uptake is high [15].

When too many devices charge without coordination, small neighborhood transformers struggle. Voltage swings become more likely under such conditions.

Harmonic noise creeps into the electrical flow as a result. Power waste increases alongside these fluctuations. Problems grow sharper where equipment runs near its limits. Older grids feel pressure even faster than expected.

Charging gets smarter when devices talk online, adjusting timing based on grid load. Instead of running anytime, they wait for quieter hours or sunny spells when solar power flows freely. These shifts happen through remote signals that guide when to start or pause. Power use spreads out more evenly across the day because of such updates. Some systems respond right away when demand changes nearby. Sunlight-heavy periods often trigger activity since supply matches need then. Decisions come from live data rather than fixed clocks. This way, strain on infrastructure drops without slowing service down.

Bouncing back during high usage times, electric vehicle batteries can give energy to the power network through Vehicle-to-Grid systems. Such setups are now under review in India as a way to balance electricity flow while supporting green sources. Instead of just drawing power, cars plugged in may return it when things get tight on the grid.

Right now, rules slow down V2G in India - bidirectional charging standards simply do not exist yet. Without them, progress stalls. Metering setups must catch up, so owners get paid fairly when their cars feed power back. On top of that, batteries wear out faster under such use, making costs climb. Each hurdle stands in its own way, separate but connected. Solutions remain distant while these gaps stay open.

Pilot projects? They're happening across India - utilities teaming up with research groups to test if vehicle-to-grid systems actually work here, checking both tech performance and cost factors [8], [10].

V. TECHNOLOGY MODELS INFRASTRUCTURE DEPLOYMENT MODELS

The charging infrastructure in India is being rolled out in four main models with each having a specific user base.

V.1 PUBLIC CHARGING NETWORKS

City spots, parking areas, and heavily used streets host them. Built around how easily drivers - both private and business - can reach quick charging points [3], [8]. Focusing the PM E-DRIVE plan on smaller urban centers pushes this setup further [26].

V.2 HIGHWAY CHARGING CORRIDORS

Fifty kilometers apart, sometimes less, charging points pop up along main roads. Found between highway exits, these spots often hold multiple CCS quick-charging units. Their job is clear: keep road-trippers moving without long waits [2], [6].

V.3 DEPOT AND CAPTIVE CHARGING

Fifty kilometers apart, sometimes less, charging points pop up along main roads. Found between highway exits, these spots often hold multiple CCS quick-charging units. Their job is clear: keep road-trippers moving without long waits [2], [6].

V.4 PERSONAL AND OCCUPATIONAL HARGING

Home remains the most common spot where electric vehicles get charged around the globe. A lack of dedicated parking spaces makes it tough in Indian cities, especially within apartment complexes packed tightly together. Right now, rules push for setting up personal charging points inside homes and workplaces - often using basic alternating current units like Type 2 plugs. These setups typically include slower AC models known as AC001 alongside similar gear.

VI. BARRIERS AND REALITIES: MOVING PAST THE OBSTACLES TO GROWTH

Not every roadblock shows up right away. Picture power lines groaning under new loads. Money talks slow when investors hesitate. Rules twist in circles, unclear and shifting. One step forward often means two sideways. Some towns welcome chargers like guests others shut doors fast. Equipment fails quietly, far from repair crews. Costs stack without warning. Officials debate while cables wait unused. Progress hides behind paperwork. Each hurdle feeds another, silently.

VI.1 STABILITY, POWER QUALITY AND GRID INTEGRATION

Folks are starting to realize that too many electric vehicle chargers might strain power systems more than expected. While local grids were built years ago, now they face fresh demands unlike anything before. Because these charging spots draw heavy loads, older infrastructure could struggle to keep up. Though some areas handle it fine today, tomorrow's growth may tell a different story. When clusters of EVs charge at once, voltage drops or

overloads become real concerns. Even equipment rated for normal use might falter under constant peak demand. So what seems manageable city by city could add up to bigger trouble down the road.

When too many electric vehicles charge at once, power levels can dip sharply. Most neighborhood transformers across India operate close to their max. Sudden demand spikes push voltages beyond safe ranges - more than the allowed six percent swing. Such stress triggers outages in small zones. Equipment wear increases, risking long-term harm to vital gear. Fixing it means expensive updates that take weeks to complete.

When electric vehicle chargers operate, they rely on power electronics that sometimes push irregular current patterns into the network. Because of those distortions, transformers can grow too hot while nearby devices suffer efficiency drops and signal issues. Some systems respond by using advanced filtering tech or adding precision circuitry to smooth out energy flow. Such upgrades tend to raise equipment expenses quite a bit. This reality shapes how charging units are designed and deployed across modern grids.[15].

When electric vehicles charge without rules, power outages tend to last longer across the network. Outage counts rise too, measured by SAIDI and SAIFI scores. Heat waves make things worse because air conditioners push demand up hard. If everyone plugs in at once during those times, the grid can struggle to keep up [15].

A surge in electric vehicles could strain power systems. Because more cars plug in, local grids may need stronger parts to handle busy times. Substations might require changes so they do not overload. Transformers can wear down faster under heavy use. Feeders may also demand improvements to keep up with rising demands. Equipment upgrades become likely when usage climbs sharply.

VI.2 HIGH CAPITAL (Capex) AND OPERATING EXPENDITURE (OPEX)

Even now, private backers see charging spots as something that can make money. Though scattered, these points keep drawing interest because they promise returns over time.

Costs for equipment can add up quickly when installing DC fast chargers, especially those running from 50 kW to 350 kW - they're far pricier than basic AC units. A single 50 kW CCS setup might demand an upfront investment of 15 lakh to 25 lakh rupees. Because of that steep price tag, launching even a modest charging station becomes tough for small or midsize businesses [2], [17].

Electricity pricing varies by state despite central guidelines meant to standardize it across regions. Even though directives exist, local utility practices shape what charging station operators actually pay. High fixed costs tied to peak usage hit hard where demand fluctuates often. Commercial power rates add strain when stations sit underused during early phases. Thin profits follow naturally when expenses stay steep but customers trickle slowly [2].

When it comes to running charging stations across India, heat, dust, and damp air make upkeep tough. Because of scorching temperatures paired with gritty particles floating around, equipment wears down faster. Humidity adds another layer of strain on electronics spread out over large areas. Keeping these units online nearly all the time - say, 99% - feels like chasing a moving target. Most companies managing such networks find themselves pouring money into repairs and checks just to stay stable.

VI.3 REAL ESTATE, URBAN, AND PERMITTING, AND LAND ACQUISITION

Finding a suitable spot for PCS in Indian cities might just be the toughest hurdle - when you skip the tech stuff. Location hunting takes time, effort, often runs into local resistance too. Picking where things go shapes how well they work later on. Some areas resist change simply because plans arrive without warning. Others struggle with space that's already stretched thin. The real issue isn't building it - it's deciding where to put it.

In big Indian cities like Mumbai and Bengaluru, housing costs soar - often above 1600 dollars for two bedrooms - making space hard to come by. Because of this squeeze, charging spots rarely pop up in separate, dedicated zones. Most public chargers today sit inside shopping centers, hotel driveways, or state-run garages instead. As a result, their placement misses many people's everyday routes [2], [17].

Parking isn't set aside for residents in many Indian cities, especially within apartment complexes. Most city dwellers live in these shared buildings, where space belongs to everyone and no one at once. Charging an electric vehicle at home becomes tricky when there's no fixed spot near your door. Since private garages hardly exist here, people lean heavily on public charging stations

instead. These outdoor hubs pick up the slack when personal setups aren't possible.

Starting a charging station still takes approvals, even without a license. Power access from the local Discom comes first. Fire safety checks follow after that. Permits from city offices also play a part. Each step drags on, sometimes for many months. Delays pile up before anything gets built [3].

VI.4 STANDARDIZATION, INTEROPERABILITY AND TECHNOLOGY RISK

Right where city streets twist into crowded corners, picking a spot for PCS often stumbles on local needs. Instead of blueprints or data, it is people's daily movement that quietly shapes the choice. Hidden patterns matter more than official maps might suggest. Even when space seems open, real access gets blocked by routines no planner predicts. What looks perfect on paper fails once foot traffic tells another story. Location hinges less on size, more on rhythm felt only after weeks of watching.

Most city dwellers in places like Mumbai and Bengaluru pay more than 1600 dollars for a two-room flat. Because space is tight, setting up separate zones for chargers becomes tricky. Many public charging points end up inside shopping centers, guest houses, or official vehicle yards instead. As a result, they sit far from where people actually need them [2], [17].

Most city dwellers in India live in apartment buildings without fixed parking spaces. Because of that, setting up personal charging stations at home becomes difficult. Home charging happens to be the top method globally. So reliance on public charging systems grows instead. References back this pattern clearly [2], [3].

Without a license, setting up an EV charger still demands several approvals. Power supply access from the local Discom comes first. Fire safety sign-off follows close behind. Permits from city offices also pile into the mix. Each checkpoint can stretch timelines - months often slip by before work even begins. Delays like these slow down how fast stations go live [3].

VII. SOCIO-ECONOMIC AND NVIRONMENTAL IMPACTS: THE GREATER VISION

The move towards electric mobility is not merely a technological one, but it has intense socio-economic and environmental consequences to India.

VII.1 ENVIRONMENTAL ADVANTAGES AND DECARBONIZATION

Driving electric cuts pollution fast - India's climate goals gain strength through charging networks. Powering vehicles without exhaust fumes shifts city air quality quickly. Cleaner transport lines up neatly with national emissions targets. Charging stations spread just as fast as demand grows. Progress shows clearly on roads and in policy alike.

One big piece of India's plan to hit Net Zero by 2070? Cleaning up how people move around. Electric vehicles shut off exhaust fumes on the spot - no more spewing carbon while driving. That win grows even bigger as power plants swap coal for sun and wind. Cleaner rides match better grids, step by step.

Starting winter, air quality dips hard across big Indian cities - index numbers sometimes hitting 300. Electric vehicles could cut out harmful NOx gases along with tiny pollution particles known as PM2.5 right where people live. Breathing troubles may drop sharply because of that shift. Health care bills tied to dirty air might shrink too. One analysis suggests switching every city bus to electric power could slash emissions in large urban centers by over half. That kind of change wouldn't just clean the sky - it'd reshape daily life on the ground.

VII.2 ECONOMICAL EFFECTS: FUEL SECURITY AND SAVINGS OF USERS

From city budgets down to household wallets, electric vehicle networks bring financial benefits. A single charging station can spark wider spending shifts across neighborhoods. Even small towns notice changes when new power systems go in. Local jobs often follow the installation of these grid updates. Big markets shift just as personal savings grow. Tax rolls rise while families spend less on fuel. Regional economies gain strength alongside individual households.

Fuel demands weigh heavy on India's economy since it buys over eight out of ten barrels from abroad. Shifting how vehicles draw power - swapping crude for current - could ease that load. Much of the needed electricity might come from within, crafted by sun, wind, or black rock beneath the soil. This switch may trim import costs while fortifying national supply lines against outside shocks.

Saving money while driving? Electric vehicles deliver that benefit straight to the wallet. For someone owning just one bike or overseeing many for business, the drop in

running expenses adds up fast. Picture spending between 0.2 and 0.5 per kilometer when charging instead of filling a tank - where prices jump to 2.0 or even 2.5. That gap matters most for people earning by delivering goods or giving rides through apps. Every rupee saved means more stability day to day.

VII.3 CREATING JOBS AND THE INDUSTRIAL ECOSYSTEM

Over twenty-nine thousand public charging points now stand across India, reshaping how industries operate. A fresh wave of activity follows where steel meets road and energy shifts form. Not just wires and poles, but entire supply chains begin to pivot. Movement grows around ports, factories hum differently. Change arrives quietly through concrete pads and blinking lights. This shift did not shout; it simply plugged in.

Homegrown EV charger makers have sprung up, shaped by local push from FAME and PM E-DRIVE efforts. While some build basic AC001 units, others now craft powerful DC fast-charging systems right within Indian factories [3], [19].

Thousands of fresh roles now appear through upkeep and setup of charging stations. Meanwhile, careers grow in power electronics thanks to rising demand from electric vehicles. Battery science sees more openings as the sector pushes forward. Software tied to managing energy systems adds further paths for workers. New chances emerge not just in cities but also across supply chains. Growth spreads into areas few expected a decade ago. Each advancement pulls in different kinds of expertise. Opportunities rise alongside technical progress in related fields.

VII.4 EQUITY, ACCESS, AND SOCIAL JUSTICE

A person’s ability to adapt matters most when building connections, since getting along with others opens doors that fairness alone might not reach. Shaped by where one stands in society, progress often grows quiet, steady work within communities that make space for everyone. Friendship becomes a kind of strength, especially when support flows both ways across shared roles.

Shifting toward electric transportation brings challenges in fairness. Getting everyone on board means tackling access gaps. Some folks face tougher roads than others do. Making sure benefits spread evenly becomes key. Not every solution fits all situations equally well.

A fresh breeze hits neighborhoods when buses run on clean fuel - folks without cars gain most, spending less while breathing easier [2], [3].

Outside big cities, smaller towns and villages often get left behind when it comes to new tech. This time though, the PM E-DRIVE plan focuses on those overlooked areas. Charging stations won’t just pop up in metros now. Instead, growth spreads wider. Rural spots gain access too. Infrastructure begins reaching places long ignored. Not every policy does this. Yet here, balance shifts toward fairness. Progress shows beyond city limits matters just as much.

Folks riding bikes for deliveries now find electric models easier on the wallet. Because swapping batteries is an option, they skip the big price tag that comes with buying one outright. This setup means less upfront cash needed just to start working. Instead of owning expensive gear, many rent what they need day by day. Costs spread out over time make life simpler between paychecks. Some even earn right after their first shift without debt hanging over them.

VIII. THE FUTURE SCOPE AND PROJECTIONS (2026-2030)

VIII.1 THE $200 BILLION OPPORTUNITY

A fresh look at India's electric vehicle scene shows big numbers ahead - NITI Aayog’s 2025 study sees a 200-billion-dollar opportunity by 2030. Charging setups are weak right now, yet fixing them could unlock most of what fuels expansion.

VIII.2 PROJECTIONS FOR 2030

Right now there are just under thirty thousand public chargers. Hitting the government's goal means growing that number dramatically - into the hundreds of thousands. Reaching thirty percent electric vehicles on the road by 2030 depends heavily on how fast new stations can be added across the country.

Out beyond the big city limits, smaller towns and villages start seeing fresh attention. Focus shifts downward through urban levels thanks to a national electric push named PM E-DRIVE. Momentum builds where it once lagged, pulled forward by policy moves marked twenty-three and twenty-six.

Fleet vehicles like taxis, delivery vans, and buses will probably drive the biggest need for chargers soon. Their shift to electric power means more plugs are coming fast.

Charging networks must grow where these vehicles work daily. Most activity won't wait - it runs on tight schedules. Expect busy hubs to fill up first. These fleets keep cities moving, so their energy needs come early. Demand spikes where wheels never stop turning.

VIII.3 EMERGING TRENDS

Power from sunlight feeds electric vehicle chargers right where it is captured - on rooftops. This link means cars can charge without drawing heavily on strained power networks. Clean energy moves straight into transport, cutting reliance on distant sources. When sunshine runs the charger, less pressure hits the main lines people depend on daily.

Charging without cords? Research into wireless power transfer continues, offering easier plug free energy delivery - though still being tested on small scale setups [13], [17].

A fresh look at next-gen battery designs shows solid-state types might charge quicker than today's versions. Charging gear could need updates because of higher energy storage abilities. Different materials inside these cells play a big role in how they perform under stress. Equipment made for older systems may struggle to keep up safely. Some changes stem from how densely power gets packed now. Engineers face new hurdles when matching hardware to cell behavior. Performance jumps come with trade-offs nobody expected five years ago.

IX. STRATEGIC RECOMMENDATIONS

Getting a strong network for electric vehicle charging means making smart moves. One way is building stations where they're needed most, not just where it's easiest. Growth happens when systems can grow without breaking down. Flexibility shows up by letting different tech work together smoothly. Long-term success comes through planning for breakdowns before they happen. Updates keep everything running even as more cars show up. Decisions made today shape how well things hold up tomorrow

Busy city spots need fast charging stations. Along busy truck routes, strong DC units go first. Placing them at transport hubs builds confidence over time. These choices help stations survive financially. Trust grows when drivers find reliable power where they stop most. Proof comes from real world use near terminals and junctions.

Piloting smart charging could begin by adjusting rules so people fill up their electric cars when demand is low. Off-peak hours might draw more users if pricing shifts gently at certain times. Some drivers may give power back to the system, provided incentives feel fair. Trials around vehicle-to-grid ideas often depend on how smoothly regulations adapt. Flexibility in tariffs can quietly shape behavior without forcing choices. Small changes in structure sometimes lead to steady participation. People tend to respond when timing aligns with ease. Frameworks supporting these efforts usually grow from real-world tests. Shifts in policy often follow where early adopters go.

One way to move forward? Set clear rules for how batteries connect across different vehicles. Shared shapes plus uniform signals between parts can unlock wider use. Think beyond single models - designs that work everywhere speed things up. Compatibility opens doors where separate systems slow progress down. Uniform access points mean simpler service networks later on. Common setups help smaller players join without rebuilding everything. When pieces fit together by default, change becomes easier over time.

Start by lowering financing costs. Risk shared between public and private sides opens doors to funding. One way is through guarantees that soften potential losses. When investors fear less, money flows easier. Support tools like partial credit backing can shift hesitation into action. Private firms then step in without waiting long. Access improves when downside feels smaller. A mix of safeguards makes lending feel safer. Confidence grows where risks are split. Lenders act faster under such conditions. Entry widens once financial weight lifts.

Starting fast means cutting delays. One desk handles both land permits and power links for charging spots. This setup trims time plus cost when rolling out stations. Rules open paths without waiting on separate steps. Getting clearances moves quicker this way. Speed comes from combining checks into one step. Paperwork flows better under one roof. Jumping through hoops slows progress less now. Simple entry points change how projects move forward. Clear lanes make space for faster builds.

X. CONCLUSION

Now things are shifting fast in India's move toward electric transport. Between FAME-I and the newer PM E-DRIVE plan, decisions began to reflect real-world data about what charging networks actually need. So far, setups exist across over 29,151 spots nationwide. Nearly 2,000 crore has gone into building out these systems. Change is taking shape, quietly but firmly. That shift? It's already underway.

One path forward leads straight into a 200 billion dollar opportunity by 2030 - but money alone won't cut it. Fast charging breakthroughs matter most, along with smarter grids, then swapping batteries like clockwork. Solving shaky power networks helps, so does lowering big setup costs, while tangled rules need untangling first. A real electric vehicle scene grows only when support lines up right - funding follows purpose. Success hides in how tightly policy moves with investors, researchers dancing step for step.

XI. REFERENCES

[1] M. Ahmad, S. S. Alam, and Y. S. Chali, "A comprehensive analysis of electric vehicle charging infrastructure, standards, policies, aggregators and challenges for the Indian market," *Energy Sources, Part A: Recovery, Util., Environ. Effects*, 2023, DOI: 10.1080/15567036.2023.2228734.

[2] S. Mishra, S. Verma, and S. S. Chowdary, "A comprehensive review on developments in electric vehicle charging station infrastructure and present scenario of India," *Sustainability*, vol. 13, no. 4, p. 2396, 2021, DOI: 10.3390/su13042396.

[3] P. Barman, S. K. Dash, and S. Mahapatra, "Charging infrastructure planning for transportation electrification in India: A review," *Renew. Sustain. Energy Rev.*, vol. 189, 2024, DOI: 10.1016/j.rser.2023.114265.

[4] S. Juyal, "Electric mobility and electric vehicles management in India," in *Electric Vehicles and the Future of Energy Storage*, Singapore: Springer, 2022, pp. 165–182, DOI: 10.1007/978-981-16-8837-9_9.

[5] S. Kishore and A. Johnvieira, "Charging infrastructure for electric vehicles: An Indian scenario," in *Socio-Economic Impact of Covid-19 on Global Business Practices*, 2022, pp. 300–307.

[6] N. Gulati, "I's FAME scheme and its extension – A real booster for electric vehicle industry," *AIP Conf. Proc.*, vol. 2452, no. 1, p. 040004, Nov. 2022, DOI: 10.1063/5.0114616.

[7] Kautilya School of Public Policy, "Powering progress: Assessment of India's EV charging infrastructure policy landscape," Hyderabad, India, Capstone Project Rep. HP21PPOL0100043, Apr. 2023. [Online]. Available: https://cms.kspp.edu.in/public/CapstoneProject/cpdocument_670f828726ead.pdf.

[8] V. K. Gaur and G. P. Yadav, "Electric vehicle charging stations in India: Challenges, business prospects, and future opportunities," *Int. J. Sci. Res. Eng. Manage.*, vol. 9, no. 2, Feb. 2025, DOI: 10.55041/IJSREM41427.

[9] S. Kohli, "Charging infrastructure in India: Incentives under FAME II and considerations for PM E-DRIVE," International Council on Clean Transportation (ICCT), Working Paper, Oct. 2024. [Online]. Available: https://theicct.org/publication/charging-infrastructure-india-fame-ii-pm-e-drive-oct24/. Accessed: Mar. 9, 2026.

[10] A. Unni, M. Singh, and R. D. Shukla, "Integrating vehicle-to-grid networks in India: Global frameworks, domestic barriers, and policy innovations," in *2025 IEEE 5th International Conference on Sustainable Energy and Future Electric Transportation (SEFET)*, 2025.

[11] M. Gowtham, S. Suresh, P. K. Keer, and K. Vaishnavi, "A comprehensive review on the evolution of electric vehicle charging infrastructure," in *2025 International Conference on Intelligent Computing, Information and Control Systems (ICOIICS)*, Nov. 2025, DOI: 10.1109/ICOIICS67115.2025.11390241.

[12] Hemavathi and S. Shinivasan, "A study on trends and developments in electric vehicle charging technologies," *J. Energy Storage*, vol. 52, 2022, DOI: 10.1016/j.est.2022.105013.

[13] T. Joseph and S. George, "'All-vehicle electrification by 2030 project' in India – Impacts and solutions," *Int. J. Electr. Syst. Autom.*, 2018, DOI: 10.26674/IJESACBT/2018/49414.

[14] S. Saklani, S. K. Singh, and A. Kumar, "Navigating the challenges of EV integration and demand-side

management for India's sustainable EV growth," *IEEE Access*, 2024, DOI: 10.1109/ACCESS.2024.3470218.

[15] S. Sasidharan and S. Singh, "Vehicle to grid integration and strategies for managed EV charging in India," in *Advances in Power and Energy Systems*, Singapore: Springer, 2022, DOI: 10.1007/978-981-16-8727-3_13.

[16] B. Kannur, "EV policy & regulations in India: An analytical study," *Indian Sci. J. Res. Eng. Manage.*, 2025, DOI: 10.55041/ijsrem.evis007.

[17] S. N. and K. S. Kumar, "A case study on wired and wireless charger standards in India for electric vehicle application," *E3S Web of Conferences*, vol. 87, 2019, DOI: 10.1051/e3sconf/20198701017.

[18] P. Kotler, "Electric vehicle adoption and penetration in India: Charging infrastructure and distribution grid upgrades as vital goals," in *Advances in Power and Energy Systems*, Singapore: Springer, 2022, DOI: 10.1007/978-981-16-8727-3_34.

[19] J. Singh and R. Sharma, "Electric vehicles for low-emission urban mobility: Current status and policy review for India," *Int. J. Sustain. Energy*, 2022, DOI: 10.1080/14786451.2022.2050232.

[20] S. Khan and M. Ali, "Electric vehicle charging infrastructure in India: Viability analysis," in *Smart Grid and Innovative Frontiers in Transportation*, Singapore: Springer, 2018, DOI: 10.1007/978-981-10-8249-8_17.

[21] NITI Aayog, "Unlocking a $200 billion opportunity," Government of India, New Delhi, Rep., Aug.2025.[Online].Available: https://www.niti.gov.in/sites/default/files/2025-08/Electric-Vehicles-WEB-LOW-Report.pdf. Accessed: Mar. 9, 2026.

[22] Ministry of Power, "Guidelines for EV charging infrastructure," Government of India, New Delhi, Sep. 17,2024.[Online].Available: https://powermin.gov.in/en/circular. Accessed: Mar. 9, 2026.

[23] Ministry of Heavy Industries, Government of India, "PM E-DRIVE operational guidelines," Sept. 26, 2025. [Online]. Available: https://pmedrive.heavyindustries.gov.in/. Accessed: Mar. 9, 2026.

[24] Ministry of Heavy Industries, Government of India, "EV charging stations," Press Information Bureau (PIB), Feb. 10, 2026. [Online]. Available: https://pib.gov.in/PressReleasePage.aspx?PRID=2225880. Accessed: Mar. 9, 2026.

[25] Kempower, "ChargeZone expands EV fast-charging network across India with Kempower technology, unveils first hub in Gujarat," Dec. 23, 2024. [Online]. Available: https://kempower.com/news/chargezone-unveils-first-hub-gujarat/. Accessed: Mar. 9, 2026.

[26] Ministry of Heavy Industries, Government of India, "EV charging stations in tier-2 cities," Press Information Bureau (PIB), Jul. 29, 2025. [Online]. Available: https://www.pib.gov.in/PressReleasePage.aspx?PRID=2149744. Accessed: Mar. 9, 2026.