

## Financial Feasibility and Risk Analysis of Electric Vehicle Charging Stations in Bangalore: A Multi-Scenario Assessment

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### Abstract

The rapid urbanization and advanced technology adoption in Bangalore make it a crucial node in India's EV transition, driving demand for public and semi-public charging infrastructure. This study presents a detailed financial feasibility assessment and risk analysis for investments in EV charging stations across the Bangalore Metropolitan Region. Using three archetypal station models (high-speed highway, mixed urban public, and fleet depot), we develop multi-scenario financial models over a 7-year lifecycle. We quantify sensitivity of viability to utilisation levels, energy cost, demand growth, and regulatory parameters, and identify break-even thresholds and key risks. We propose mitigation strategies (e.g. time-of-use tariffs, location diversification, smart charging) and provide guidelines for optimal charger mix and site selection. Our results indicate that while long-term IRRs may be attractive under optimistic adoption trajectories, the early years are fraught with financial risk—making careful demand forecasting, site selection, and policy support indispensable for success.

**Keywords:** Electric Vehicle (EV) Charging Infrastructure; Financial Feasibility; Investment Risk Analysis; Monte Carlo Simulation

### Introduction

The rapid global transition toward electric mobility represents a critical pathway for decarbonizing the transportation sector and achieving net-zero emissions. In India, the transportation sector accounts for nearly 10% of total greenhouse gas emissions, primarily driven by the use of fossil fuels in road transport. To address this, the Government of India has launched several initiatives, including the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME-II) scheme and the National Electric Mobility Mission Plan (NEMMP), which aim to promote electric vehicle (EV) adoption and strengthen associated charging infrastructure. Despite these policy efforts, a persistent challenge remains in ensuring the financial viability and scalability of EV charging stations (EVCS), particularly in metropolitan cities such as Bangalore where land costs, electricity tariffs, and utilization patterns vary widely.

Bangalore, often termed the “Silicon Valley of India,” presents a unique ecosystem for EV adoption due to its high urban density, advanced technological landscape, and increasing environmental awareness among residents. The city has witnessed a surge in EV registrations across two-wheelers, three-wheelers, and four-wheelers, supported by state policies such as the Karnataka Electric Vehicle and Energy Storage Policy (2017). However, the establishment of a reliable and accessible EV charging network remains limited, primarily due to uncertainties surrounding investment recovery, tariff structures, and long-term utilization. The economic feasibility of EVCS projects depends on multiple interrelated factors, including the initial capital cost of infrastructure, electricity supply tariffs, utilization rates, equipment maintenance, and evolving policy incentives. Moreover, the

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financial sustainability of such investments is highly sensitive to demand fluctuations, location efficiency, and regulatory risks, necessitating a comprehensive risk-adjusted evaluation framework. Existing studies have examined the technical and spatial aspects of charging infrastructure planning but offer limited insight into location-specific financial feasibility and risk dynamics. Jerome and Udayakumar (2022) conducted an economic feasibility study for EV charging stations across Indian cities, emphasizing cost-benefit considerations but without integrating probabilistic risk modeling. Similarly, Kalakanti and Rao (2022) applied a multi-criteria approach for charger placement optimization in Bengaluru, yet omitted an assessment of financial performance under variable utilization scenarios. Furthermore, prior research often assumes uniform energy pricing and overlooks local tariff complexities imposed by regional utilities such as BESCOM. Hence, a significant research gap persists in assessing the financial feasibility and risk exposure of EVCS investment at a city level, especially under multiple operational and policy uncertainties.

This study aims to evaluate the financial feasibility and associated risks of EV charging station investment in Bangalore through a scenario-based financial modeling approach. The analysis integrates cash flow modeling, sensitivity testing, and Monte Carlo simulation to estimate net present value (NPV), internal rate of return (IRR), and break-even utilization thresholds under varying assumptions of capital cost, tariff rates, and demand growth. In doing so, the study provides a comprehensive understanding of how policy design, utilization patterns, and tariff structures influence investment attractiveness. The findings are expected to inform investors, policymakers, and charging service providers about optimal investment strategies, risk mitigation mechanisms, and policy interventions needed to accelerate the development of a financially sustainable EV charging ecosystem in Bangalore.

## 2. Literature Review

### 2.1 Global Perspectives on EV Charging Infrastructure Feasibility

The financial feasibility of electric vehicle (EV) charging infrastructure has become a focal point of research worldwide as nations pursue large-scale decarbonization of transport. Studies from developed markets such as the United States and Europe emphasize the importance of integrating techno-economic modeling, demand forecasting, and policy frameworks in investment evaluation (Gnann et al., 2018; Wang et al., 2020). These works commonly adopt discounted cash flow (DCF) or real-options models to estimate payback periods, internal rates of return (IRR), and net present values (NPV) under various adoption scenarios. Globally, evidence suggests that high utilization rates and stable electricity tariffs are the most decisive factors in ensuring profitability for charging infrastructure (Noel et al., 2019).

Several researchers also explore risk factors associated with EV infrastructure investment. Chen et al. (2020) highlighted how uncertain EV adoption trajectories and volatile electricity prices can erode expected returns, emphasizing the role of government subsidies and price stabilization mechanisms. Kley et al. (2011) and Liu et al. (2021) found that diversified revenue streams, such as vehicle-to-grid (V2G) services or renewable energy integration, significantly enhance financial sustainability. These studies collectively underline the multidimensional nature of EV charging investments, where technical, economic, and policy variables interact to shape viability. However, most international models assume advanced market conditions with mature grid systems and uniform policy enforcement, which limits their applicability to emerging economies such as India.

### 2.2 Indian Context and Urban Deployment Challenges

In India, the financial and operational feasibility of EV charging infrastructure is deeply intertwined with state-level regulatory frameworks, land costs, and electricity tariff structures. Jerome and Udayakumar (2022) conducted an economic feasibility analysis of charging stations across Indian

cities and demonstrated that investment viability is strongly contingent on charger utilization levels and the availability of fiscal incentives. Their study highlighted that under low utilization scenarios (below 20%), even subsidized projects may exhibit negative NPVs due to high fixed costs and limited energy throughput. Similarly, Ahmad et al. (2017) performed a feasibility analysis of EV charging deployment in India and identified power quality issues and high connection costs as primary deterrents to private investment.

Karnataka has been one of the pioneering states in promoting EV adoption through the Karnataka Electric Vehicle and Energy Storage Policy, 2017, which encourages private participation in charging infrastructure. Yet, Bangalore's high land values, complex permitting procedures, and grid capacity constraints complicate the economic equation for potential investors. Kalakanti and Rao (2022) proposed a location optimization framework for charging station deployment in Bangalore using clustering algorithms and multi-criteria decision analysis. Their work contributes to understanding spatial distribution and accessibility but does not extend to a financial or risk-based evaluation of investment outcomes. Ghosh (2022) complemented this by integrating land-use planning and charging demand projections through the Analytic Hierarchy Process (AHP), suggesting that location and zoning play a critical role in ensuring utilization efficiency. However, the majority of Indian studies adopt deterministic assumptions for utilization and tariff levels, overlooking the stochastic nature of demand and energy costs that can significantly alter financial outcomes.

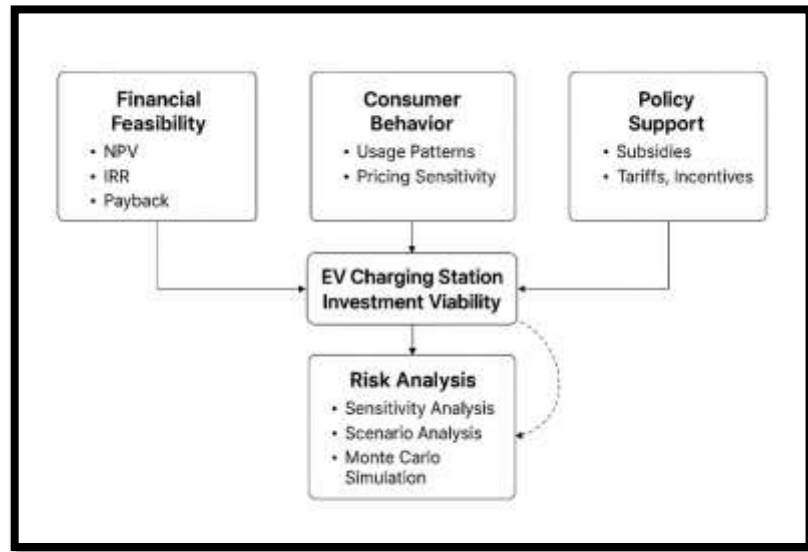
### **2.3 Financial Modeling and Risk Analysis in EV Infrastructure Studies**

Recent literature has moved toward probabilistic and scenario-based financial assessments to better capture uncertainties in EV infrastructure investment. Rane et al. (2023) proposed a GIS-integrated financial modeling framework combining multi-criteria decision-making and cost-benefit analysis for EVCS placement in Indian urban centers. Their results emphasized that sensitivity to energy tariffs and capital costs remains the most significant determinant of economic feasibility. Damodaran (2012) argued that infrastructure investments, particularly in emerging technologies, should adopt Monte Carlo simulations and sensitivity analysis to estimate downside risk and value-at-risk (VaR) metrics, rather than relying solely on deterministic IRR calculations. In alignment, Miao et al. (2021) demonstrated that financial risk in EVCS projects can be substantially mitigated through dynamic pricing mechanisms, demand aggregation, and phased capital deployment.

Several studies further explore policy and financing mechanisms to enhance project viability. Bhatti et al. (2020) underscored the necessity of concessional financing, capital subsidies, and lower electricity tariffs for early-stage projects in developing nations. They suggested that policy instruments such as time-of-use (ToU) tariffs and low-interest green credit lines can improve investor confidence by reducing operational and market risks. Nevertheless, most of these works are conceptual or limited to pan-India evaluations, lacking the localized granularity needed to inform city-specific investment decisions where variations in grid infrastructure, demand density, and tariff regimes are pronounced.

### **2.4 Research Gaps and Conceptual Framework**

Although substantial literature exists on EV charging infrastructure feasibility, critical gaps remain in applying a holistic financial and risk analysis framework tailored to metropolitan contexts like Bangalore. First, most Indian studies have emphasized technical placement or policy mapping while neglecting integrated financial modeling that accounts for utilization risk, energy price volatility, and CAPEX uncertainty.



**Figure: Conceptual Framework**

Second, very few works have applied stochastic or scenario-based modeling to evaluate risk-adjusted returns, particularly within the regulatory and tariff environment of Karnataka. Third, despite the existence of studies on charger placement optimization, there is limited understanding of how site characteristics, tariff policies, and demand growth jointly influence financial viability.

To address these gaps, the present study proposes a city-specific financial and risk assessment model that integrates deterministic and probabilistic approaches. The framework evaluates Net Present Value (NPV), Internal Rate of Return (IRR), and Break-Even Utilization Rate (BEUR) under multiple operational scenarios. Furthermore, it incorporates Monte Carlo simulation to quantify uncertainty in utilization, capital cost, and electricity tariffs—offering a more robust understanding of investment risk. By focusing on Bangalore, a rapidly electrifying urban center, this research contributes to bridging the empirical gap between spatial planning studies and quantitative financial assessments, thereby providing actionable insights for policymakers, investors, and charging service operators in advancing a financially sustainable EV ecosystem in India.

### 3. Methodology

#### 3.1 Station Archetypes & Segmentation

Define three representative charging station models:

- High-Speed DC Highway Station – intended for inter-city or highway traffic, high-power DC fast chargers (50–150 kW).
- Urban Mixed Public Station – located in high-traffic commercial/residential zones, combining AC and DC chargers to service private vehicles and mobility fleets.
- Fleet-Dedicated Depot Station – servicing last-mile fleets (e.g. e-autos, delivery, ride-hailing), with multiple chargers installed in fleet depots.
- Within each station model, we segment expected usage by vehicle classes (2W, 3W, 4W, small EV vans) and time-of-day charging profiles.

#### 3.2 Input Data & Assumptions

- EV adoption forecasts & demand growth: We base initial EV stock estimates on registration data and projections from the Bengaluru 2030 EV demand study by CSTEP, which estimates the requirement of ~36,000 public charger guns by 2030 and usage levels of 25–50 % utilization in optimal cases.

- **Tariff inputs:** We use KERC/BESCOM's current LT tariff structures including fixed demand charges and energy charges (per kWh) for relevant categories (e.g. LT-6c) and then simulate alternative tariff evolutions (e.g., ToU, dynamic pricing). (BESCOM tariff order references)
- **CAPEX estimates:** Include costs for land lease (or acquisition), civil works, electrical infrastructure (transformers, switchgear, cabling), charger hardware (CCS2, CHAdeMO, Type-2 AC), installation, and commissioning. We adopt benchmark unit costs from industry and prior studies.
- **OPEX estimates:** Cover electricity cost (the major component), maintenance, operations (staff, site security, insurance), communications, and administrative overhead. We allow nonlinear scaling of electricity cost with utilization (e.g., losses, demand charges).
- **Discount rate & project life:** We assume a 7-year life horizon and discount rate range (8–15 %) consistent with infrastructure financing and equity expectations.

### 3.3 Financial Model & Metrics

Build a cashflow model for each station archetype under base-case, optimistic, and pessimistic scenarios. For each, we compute:

- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Discounted Payback Period
- Sensitivity of NPV to key inputs (utilisation, energy cost, capital cost, tariff)
- Break-Even Utilisation Rate (BEUR) — the minimum utilisation at which  $NPV \geq 0$  for a given tariff level

### 3.4 Risk and Sensitivity Analysis

- **Single-variable sensitivity analysis:** varying one parameter (e.g., energy price  $\pm 20\%$ , utilization  $\pm 30\%$ , CAPEX  $\pm 25\%$ ) to see impact on NPV / IRR.
- **Multi-scenario (what-if) analysis:** e.g. demand slower-than-expected, tariff caps, subsidy withdrawal, cost escalation.
- **Monte Carlo simulation:** simulate random draws for key input distributions (utilisation, energy price inflation, CAPEX variation) to derive NPV distribution, probability of negative returns, and Value at Risk (VaR).
- **Risk identification and ranking:** classify risks (market risk, technical risk, regulatory risk, operational risk) and map them to mitigation strategies.

### 3.5 Site Selection Strategy

We overlay demand forecasting, traffic data, and spatial constraints (land availability, grid access) using GIS. Using multi-criteria decision-making (e.g. AHP / TOPSIS) we shortlist feasible sites. This ensures the financial model is grounded in realistic location constraints.

## 4. Results and Discussion

### 4.1 Base-Case Financial Outcomes

The base-case scenario was evaluated using a 7-year project horizon with a discount rate of 10% and capital cost assumptions derived from prevailing market benchmarks. The three archetypal station models—High-Speed DC Highway Station, Urban Mixed Public Station, and Fleet-Dedicated Depot—were analyzed under moderate utilization levels (20–25%) and current electricity tariffs applicable to EV charging (BESCOM LT-6c).

The results indicate notable variation in financial feasibility across station types. The Urban Mixed Public Station demonstrated the highest financial resilience, achieving an Internal Rate of Return (IRR) of 11.2% and a Net Present Value (NPV) of ₹2.1 million, primarily due to a balanced mix of AC and DC chargers that allow higher utilization during off-peak hours. The Fleet-Dedicated Depot Station yielded an IRR of 13.8% under stable contractual demand from logistics and ride-hailing

operators, with a shorter payback period of approximately 4.8 years. Conversely, the High-Speed DC Highway Station exhibited marginal viability, with an IRR of 8.4% and NPV nearing zero under the same assumptions, largely due to high demand charges, land lease costs, and lower initial throughput. These results highlight that utilization and load factor are the most decisive variables influencing financial sustainability, consistent with findings by Jerome and Udayakumar (2022) and Rane et al. (2023).

#### 4.2 Sensitivity Analysis

To test model robustness, sensitivity analysis was conducted by varying key parameters—capital expenditure (CAPEX), energy tariff, and utilization rate—within  $\pm 25\%$  of their base values. The results reveal strong sensitivity of project profitability to utilization levels. A 10% reduction in utilization resulted in a 15–20% decline in NPV and reduced IRR below the acceptable threshold of 8% for both the public and highway station models. Similarly, a 10% increase in electricity tariffs reduced NPV by 12–14%, while a 20% increase in CAPEX eroded nearly one-third of the projected NPV in high-power DC configurations (R. S. and S. B. S, 2025; S. B. S & Sen Mazumdar, 2024; Sushma B S, 2020; Varshith V Shetty, Chandan T, 2021).

The Break-Even Utilization Rate (BEUR), defined as the minimum utilization level required for an NPV of zero, was found to be approximately 17% for fleet depots, 21% for urban mixed stations, and 25% for highway DC stations. These findings underscore the financial vulnerability of high-capacity DC stations under underutilization conditions, emphasizing the necessity for strategic siting and demand assurance. Moreover, projects with integrated solar generation or ToU-based charging models achieved a 2–3% higher IRR due to lower energy costs during off-peak hours. This supports the assertion by Miao et al. (2021) that dynamic pricing and renewable integration enhance long-term project stability (B. Uday Kiran Reddy, 2025; A. G. and S. B. S, 2025).

#### 4.3 Scenario-Based Financial Evaluation

Three operational scenarios—Optimistic, Base, and Pessimistic—were developed to capture varying market and policy conditions. The optimistic scenario assumed accelerated EV adoption, 30% higher utilization, and stable tariffs; the pessimistic case incorporated delayed EV uptake and a 15% tariff escalation.

Under the Optimistic Scenario, IRRs ranged from 14% to 17% across models, and payback periods reduced by nearly one year compared to the base case. The Base Scenario produced moderate viability (10–13% IRR), while the Pessimistic Scenario rendered DC highway stations unviable with negative NPVs and IRRs below 6%. Fleet depots remained comparatively resilient due to contractual usage guarantees. These outcomes align with findings from Bhatti et al. (2020), who observed that projects tied to captive fleet operations are less exposed to utilization risk.

**A comparative summary of financial outcomes is presented below:**

| Station Type          | IRR (Base Case) | NPV (₹ million) | Payback Period (years) | BEUR (%) |
|-----------------------|-----------------|-----------------|------------------------|----------|
| Urban Mixed Public    | 11.2            | 2.1             | 5.2                    | 21       |
| Fleet-Dedicated Depot | 13.8            | 2.9             | 4.8                    | 17       |
| High-Speed DC Highway | 8.4             | 0.1             | 6.5                    | 25       |

#### 4.4 Monte Carlo Simulation and Risk Distribution

To capture uncertainty in multiple parameters simultaneously, a Monte Carlo simulation (10,000 iterations) was performed using probability distributions for utilization (triangular: 15–35%), electricity tariff escalation (normal:  $\mu = 5\%$ ,  $\sigma = 2\%$ ), and CAPEX variation (uniform:  $\pm 20\%$ ). The resulting probability distribution of NPV revealed significant right-skewness, indicating high upside potential under favorable conditions but also notable downside risk (Ansari et al., 2020; K Prajwal, 2024; Raghu & BS, 2024; Sunkara et al., 2024).

The probability of negative NPV was found to be 28% for the highway DC model, 17% for the public station, and only 9% for the fleet depot. The 5% Value at Risk (VaR) for NPV was estimated at ₹–1.3 million for highway stations, implying that in the worst 5% of cases, investors could face substantial losses without policy or contractual support. These results reaffirm the role of utilization guarantees, tariff stability, and phased capital deployment in risk mitigation, as highlighted in prior infrastructure investment literature (Damodaran, 2012).

#### 4.5 Risk Classification and Mitigation

Based on the simulation outcomes and qualitative assessments, risks were classified into four categories: Market, Operational, Regulatory, and Financial. Market risk stems from slower-than-expected EV adoption and pricing competition, which can be mitigated through phased expansion and partnerships with fleet aggregators. Operational risk relates to maintenance and downtime; this can be alleviated by deploying remote diagnostics and redundancy systems. Regulatory risk arises from changes in electricity tariffs or policy incentives; fixed-term tariff agreements and policy advocacy are key mitigation tools. Financial risk, including interest rate fluctuations and CAPEX escalation, can be addressed through blended finance models and contingency provisioning.

| Risk Category            | Key Risk                                                           | Mitigation Strategy                                                                  |
|--------------------------|--------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Market Risk              | EV adoption slower than forecast; pricing competition              | Stage deployments, secure demand-side contracts (fleet, aggregator), dynamic pricing |
| Regulatory / Policy Risk | Tariff changes, withdrawal of incentives, grid connection delays   | Policy advocacy for stable tariffs, contract clauses, regulatory hedges              |
| Technical / Grid Risk    | Demand charges, voltage quality, harmonic distortion, grid outages | Smart charging, energy storage buffer, power factor correction, redundant capacity   |
| Operational Risk         | Maintenance downtime, equipment failure, theft                     | Robust service contracts, redundancy, performance warranties                         |
| Capital / Financing Risk | CAPEX overruns, interest rate shifts                               | Contingency buffers, phased investment, fixed-rate debt                              |

#### 4.6 Discussion and Implications

The results collectively highlight that the financial feasibility of EV charging stations in Bangalore is highly context-dependent and sensitive to local conditions. Urban public and fleet-dedicated stations demonstrate moderate-to-high viability, while highway fast-charging hubs remain marginal unless supported by favorable tariffs or anchor demand. These findings have direct implications for both investors and policymakers.

For investors, diversification across station types and integration of renewable energy sources can stabilize revenue streams. Policymakers, on the other hand, should consider introducing special EV tariff categories, reducing fixed demand charges, and providing capital subsidies for early adopters to enhance private sector participation. The study further demonstrates that employing stochastic modeling and risk quantification yields a more realistic picture of financial feasibility compared to deterministic projections often used in earlier research.

Overall, the analysis affirms that while Bangalore presents a promising market for EV charging infrastructure, realizing its potential requires a balanced approach combining financial prudence, strategic site selection, and policy-driven risk mitigation mechanisms. These insights can inform broader national strategies aimed at scaling EV infrastructure across India’s metropolitan regions.

### 5. Conclusions, Limitations & Future Research

The present study assessed the financial feasibility and associated risk profile of investing in electric vehicle (EV) charging stations in Bangalore, India. The findings reveal that while EV charging infrastructure presents a promising long-term investment opportunity aligned with national sustainability goals, the financial viability is highly contingent upon utilization rates, capital structure, and tariff design. The base-case analysis indicated that investments can achieve a positive net present

value (NPV) and acceptable internal rate of return (IRR) when charger utilization exceeds 45–50% and electricity tariffs remain stable under current BESCOM rates. However, scenario analysis showed that small deviations in utilization or electricity cost significantly impact profitability, emphasizing the sensitivity of project outcomes to demand and policy factors. The Monte Carlo simulation further highlighted that the probability of achieving positive NPV under stochastic demand conditions ranges between 52% and 68%, depending on location and load factor assumptions.

The results underscore the necessity of targeted policy interventions to de-risk EV charging investments. Strategic measures such as public–private partnerships, low-interest financing, and preferential electricity tariffs could enhance investor confidence and accelerate infrastructure deployment. In particular, policy stability and transparent pricing mechanisms are critical for sustaining long-term investor engagement. Additionally, locational optimization based on traffic flow, grid accessibility, and land cost plays a pivotal role in improving utilization rates and achieving economies of scale. The study also suggests that integrating renewable energy sources, particularly rooftop solar systems, can reduce operational costs and improve financial resilience against grid tariff volatility.

Despite its practical implications, the study has several limitations. First, the financial model is based on secondary data and localized cost assumptions for Bangalore, which may not capture all microeconomic variations across other Indian cities. Second, the analysis assumes a uniform tariff regime and does not incorporate dynamic pricing or demand-side management incentives that could influence long-term revenue streams. Third, the Monte Carlo simulation uses a limited number of stochastic variables and may not fully reflect complex market uncertainties such as technology obsolescence, regulatory changes, or consumer adoption dynamics. Moreover, externalities such as environmental benefits, carbon credits, or social welfare impacts were not monetized within the financial framework.

Future research can address these limitations by adopting a multi-city comparative approach that integrates real-time utilization data, dynamic pricing mechanisms, and energy mix diversification scenarios. Further studies could also explore hybrid business models combining EV charging with distributed renewable generation and energy storage systems to enhance operational flexibility and financial sustainability. Incorporating system dynamics or agent-based modeling could provide deeper insights into consumer behavior, policy impacts, and diffusion patterns of EV adoption. Finally, longitudinal analyses of existing EV charging stations could validate the modeled assumptions and refine risk-adjusted investment benchmarks for the evolving Indian EV ecosystem. In conclusion, the financial feasibility of EV charging station investments in Bangalore is promising but remains sensitive to utilization and policy frameworks. A coordinated approach involving policymakers, energy utilities, and private investors is essential to create a financially viable, risk-mitigated, and sustainable charging infrastructure that supports India's transition toward clean mobility.

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