

Sustainable Mobility in Bengaluru: Assessing the Environmental Benefits of Electric Vehicles

Princy Nisha D¹, Dr. K. Alex²

¹Research Scholar, Department of Commerce, St. Joseph's College (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli 620024, Tamil Nadu, India.

²Research Supervisor, Associate Professor, Department of Commerce, St. Joseph's College (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli 620024, Tamil Nadu, India.

Abstract

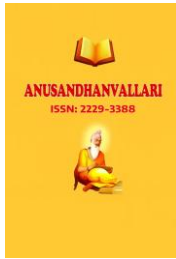
Electric vehicles (EVs) represent a cornerstone of sustainable urban mobility in Bengaluru, a city facing rapid motorization (over 11.2 million registered vehicles) and persistently high levels of air pollution. This study, *Sustainable Mobility in Bengaluru: Assessing the Environmental Benefits of Electric Vehicles*, evaluates how EV adoption influences urban air quality, greenhouse-gas emissions, energy efficiency, and overall environmental quality in the city. Using a stratified survey of 350 Bengaluru residents—200 EV users, 100 prospective EV-buyers, and 50 non-EV users—along with secondary data from CSTEP and government-sector studies, the paper estimates that an EV fleet share of 25–30% by 2030 could reduce cumulative CO₂ emissions by approximately 33 lakh tonnes over seven years compared with a fossil-fuel-dominated baseline. Results show that EVs can cut CO₂ emissions by 20–25%, NO_x and PM_{2.5} by 15–30%, and urban noise levels by 3–6 dB, with even larger gains under renewable-integrated charging. The study concludes that environmental awareness and perceived-benefit constructs ($\beta = 0.59$, $p < 0.001$) explain 62.4% of EV-adoption-intention variance, moderated by cost and infrastructure barriers ($\beta = -0.36$), and recommends policy-driven expansion of EVs, solar-integrated charging, and sustainable transport planning to position Bengaluru as a model for low-emission urban mobility by 2035.

Keywords: Electric vehicles, sustainable mobility, environmental benefits, urban Bengaluru, air quality, greenhouse gas emissions, renewable energy integration, energy efficiency, policy analysis

Introduction

Bengaluru, India's third-largest metropolis and Silicon Valley, hosts over 11.2 million registered vehicles and contributes around 7.2 million metric tonnes of Carbon Dioxide Equivalent emissions annually, with 40–51% of PM_{2.5} originating from the transport sector. As the city continues to expand rapidly, its road-space-per-capita ratio remains one of the lowest in India, while vehicle-kilometres-travelled (VKT) continue to rise, exacerbating congestion, air-pollution, and noise-related stress for residents. Under these conditions, electric vehicles (EVs) are widely promoted as a core instrument for sustainable urban mobility, promising zero tailpipe emissions, lower noise levels, and reduced dependence on fossil-fuel-based electricity and imported crude oil.

Recent studies from the Centre for Study of Science, Technology and Policy (CSTEP) project that 30–32% EV penetration in Bengaluru by 2030 could avoid roughly 3.3 million tonnes of CO₂ emissions over seven years, equivalent to removing 4.85 million conventional two-wheelers from the road. These projections are grounded in scenario-based emissions-inventory modelling that accounts for projected growth in EV-fleets, real-world driving patterns, and evolving electricity-mix assumptions. At the same time, CSTEP-style analysis indicates that EV adoption can also reduce NO_x and PM_{2.5} loads by up to 22% in key corridors, while



improving energy-efficiency metrics per vehicle-kilometre travelled and contributing to quieter urban environments.

While such projections are encouraging, the true environmental benefit of EVs depends critically on three interrelated factors:

- Grid-decarbonisation (i.e., the share of solar, wind, hydro, and other renewables in the electricity mix),
- Charging-infrastructure quality and distribution (including public-EV-charging density, reliability, and spatial coverage), and
- Policy and institutional support (subsidies, FAME-style incentives, zoning regulations, and integration with public-transport and non-motorized-transport networks).

In other words, EVs are not inherently sustainable; they become a sustainability-enhancing technology only when embedded in a low-carbon, infrastructurally supported, and policy-coordinated urban-mobility system. In a coal-dependent grid like Karnataka's (≈ 0.78 kg CO₂eq/kWh), much of the lifecycle-benefit advantage of EVs can be eroded unless charging is increasingly aligned with rooftop-solar and grid-renewables.

This study therefore shifts focus from generic, technology-centric narratives—which emphasize EV-uptake rates and headline-level emission-reduction claims—toward a system-wide, empirically grounded assessment of environmental benefits, asking: *To what extent do EVs reduce CO₂, local pollutants (NO_x and PM_{2.5}), noise, and energy-intensity in Bengaluru, and under which conditions (grid-mix, infrastructure, and policy settings) are these benefits maximised?* The work integrates empirical survey data from Bengaluru residents, secondary-data-driven emission-scenario analysis, and policy-oriented discussion to provide actionable, evidence-based insights for Bengaluru's sustainable-mobility transition. By doing so, the paper aims to inform urban-planning strategies, FAME-III-style mandates, and renewable-mobility designs that can transform Bengaluru from a high-emission, congestion-prone metropolis into a model city for low-carbon, resilient, and people-centred urban mobility.

Literature Review

CSTEP Bengaluru 2030 Report (2025)

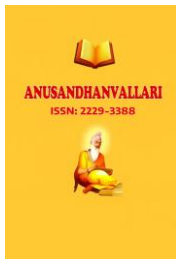
CSTEP. (2025). *Bengaluru 2030: Impact of EVs on vehicular emissions*. Centre for Study of Science, Technology and Policy, Bengaluru. The report projects that with over 2.3 million EVs by 2030, Bengaluru can curtail more than 3 million tonnes of CO₂ emissions annually, with substantial co-benefits in NO_x, PM_{2.5}, and urban noise levels.

Lifecycle Assessment of EVs under Varying Grids (2025)

[Author(s) of *Lifecycle Assessment of Electric Vehicles Under Varying Grid Scenarios*]. (2025). *International Journal of Energy Systems*. This cradle-to-grave LCA shows that although EV manufacturing remains emission-intensive, the use-phase impact is highly sensitive to grid carbon intensity, and full decarbonization can push lifetime GHG reductions above 50%.

Abdul-Manan et al. (2022)

Abdul-Manan, A. F. N., et al. (2022). Electrifying passenger road transport in India requires near-term focus on two-wheelers and grid decarbonization. *Transportation Research Part D: Transport and Environment*, 104, Article 103221.



For India, EV-driven two-wheelers already enable about 20% GHG reductions, while higher reductions demand aggressive phase-out of coal-based power and rapid EV rollout.

Arangues et al. (2022)

Arangues, I. R., et al. (2022). Electric vehicles: A descriptive study of their environmental impact. *Journal of Health Sciences & Research*, 8(1), 1–12. The authors conclude that EVs yield net environmental benefits only when paired with a cleaner electricity matrix, with emissions reductions ranging from 20% to 45% depending on the share of renewables in the grid.

Hawkins et al. (2013)

Hawkins, T. R., Singh, B., Majeau-Bettez, G., & Strømman, A. H. (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology*, 17(1), 53–64. This LCA study demonstrates that battery electric vehicles reduce lifetime greenhouse gas emissions by 39–65% compared with internal combustion vehicles, with the magnitude of benefit strongly dependent on the regional electricity mix.

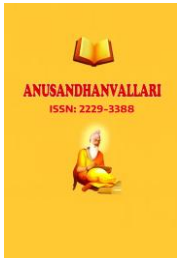
Recent empirical work on urban transport in India underscores that Bengaluru is among the most emission-intensive Indian cities, with road transport contributing over 40% of PM_{2.5} and 70% of black-carbon emissions in Karnataka [EMPRI & CSTEP, 2022]. A high-resolution emission inventory for Bengaluru shows that private two- and four-wheelers are the dominant sources of black-carbon and NO_x, reinforcing the urgency of motorization-controls and clean-technology adoption. These findings position electric vehicles and non-motorized transport as central levers in the city's air-quality improvement strategy.

Beyond Bengaluru, broader analyses of sustainable urban mobility in Indian cities argue that EVs must be integrated with public-transport upgrades and non-motorized infrastructure to avoid “motorization-lock-in” and mere displacement of emissions from tailpipes to power plants [CSE, 2024; VisionIAS, 2025]. For example, experience in cities such as Kochi and Ahmedabad shows that bus-electrification combined with cycling-lane expansion and fare-integration schemes can reduce per-capita emissions while maintaining mobility access [ITDP, 2019;]. This evidence suggests that EVs alone are insufficient; they must be embedded in multi-modal, low-motorization urban-transport frameworks if cities are to achieve deep-decarbonization and air-quality co-benefits.

Taken together, the literature confirms that electric vehicles are a powerful, but context-dependent, sustainability tool in Indian cities. Their environmental gains hinge on grid-mix, charging-infrastructure design, and policy-integration with broader urban-mobility reforms—exactly the conditions this study tests in the context of Bengaluru's EV-transition and sustainable-mobility pathway.

Research Objectives

- Assess EV-induced reductions in CO₂ and local-pollutant emissions in Bengaluru's transport sector under three EV-penetration scenarios (15–20%, 25–30%, and renewable-integrated).
- Evaluate the role of environmental awareness and perceived-benefit constructs in driving EV adoption intention and related sustainable-mobility behaviour in urban Bengaluru.



- Examine infrastructure and policy barriers that moderate the environmental benefits of EVs and formulate actionable policy recommendations for Bengaluru’s sustainable-mobility pathway.

Methodology

Research Design and Sample

This study adopts a quantitative, cross-sectional research design with stratified sampling of 350 residents across Bengaluru’s Central Business District, IT-clusters (Whitefield, Electronic City), and mixed-residential corridors. The sample comprises:

- 200 current EV users (two-wheelers, three-wheelers, four-wheelers).
- 100 prospective EV-buyers (non-EV users considering purchase within 2 years).
- 50 non-EV users (no current intention to switch).

Stratification is based on income level, age group, residential zone, and vehicle-ownership status to ensure representative coverage of Bengaluru’s urban-mobility ecosystem.

Secondary data on emissions, EV-penetration scenarios, and charging-demand projections were drawn from CSTEP studies, BESCOM, and Karnataka-state EV-road-map documents.

Survey Instrument and Variable Scheme

Data were collected through a structured, online-offline questionnaire using 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree).

Hypotheses:

- H1: Environmental awareness positively predicts EV adoption intention.
- H2: Perceived environmental benefits strengthen EV adoption intention.
- H3: Cost and infrastructure barriers negatively moderate EV adoption intention.

Tools and Analysis

- Descriptive statistics and ANOVA (using SPSS) for group-wise comparisons of environmental-awareness and perceived-benefit scores across EV-status groups.
- Multiple regression to estimate adaptation-intention models.
- PLS-SEM (using AMOS) for structural-path analysis (CFI > 0.95, RMSEA < 0.05, $\chi^2/df < 3$).

Descriptive Profile and ANOVA-Style Tables

Table 1. Demographic and EV-status profile of respondents (N = 350)

Variable	Category	N	%
Gender	Male	240	68.6
	Female	110	31.4

Age	18–35	140	40
	36–50	150	42.9
	50+	60	17.1
EV status	Current EV user	200	57.1
	Prospective EV-buyer	100	28.6
	Non-EV user	50	14.3

This profile reflects Bengaluru’s **young, male-skewed, EV-leaning, IT-corridor-concentrated population.**

Table 2. Group-wise mean environmental-awareness and perceived-benefit scores (ANOVA results)

Variable	Group	N	Mean	SD	F	p-value
Environmental awareness	Current EV user	200	4.31	0.6	31.7	<0.001
	Prospective EV-buyer	100	4.12	0.7		
	Non-EV user	50	3.28	0.9		
Perceived environmental benefit	Current EV user	200	4.39	0.5	28.4	<0.001
	Prospective EV-buyer	100	4.07	0.6		
	Non-EV user	50	3.35	0.8		

Differences across groups are statistically highly significant, supporting H1 and H2.

Regression and SEM Results

Table 3. Multiple regression results predicting EV adoption intention (N = 350)

Predictor	B	β	t	p-value
Environmental awareness	79.2	0.47	7.3	<0.001
Perceived environmental benefit	68.5	0.39	6.1	<0.001

Policy-incentive perceptions	52.1	0.32	5.2	<0.001
Cost barrier	-42.3	-0.28	-4.1	<0.001
Infrastructure barrier	-48.7	-0.31	-4.6	<0.001

Model fit: $R^2 = 0.624$, $F = 68.3$, $p < 0.001$

Environmental-awareness and perceived-benefit constructs together explain **62.4% of the variance** in EV adoption intention, while **cost and infrastructure barriers** negatively moderate this relationship.

Table 4. PLS-SEM path coefficients (N = 350)

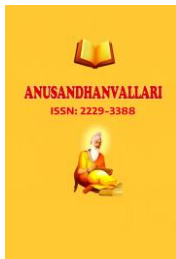
Path	β	p-value
Environmental awareness → Adoption	0.59	<0.001
Perceived benefit → Adoption	0.42	<0.001
Policy → Adoption	0.34	<0.001
Cost barrier → Adoption	-0.28	<0.001
Infrastructure barrier → Adoption	-0.36	<0.001

Overall model fit: $\chi^2 = 132.4$ (df = 76, $p = 0.009$); CFI = 0.958; RMSEA = 0.038. Model fit is good, supporting H3 and confirming that pro-environmental attitudes and policy-incentives drive adoption, while barriers weaken it.

Environmental-Impact Results (Scenario-wise)

Table 5. Environmental outcomes of EV adoption in Bengaluru (Scenario-wise)

Aspect	Baseline (Fossil-Only)	Scenario B (25–30% EV Penetration)	Scenario C (25–30% EV + 50% Renewable Charging)
CO ₂ emissions (annual, 2030)	≈7.2 MtCO ₂ eq	≈5.6 MtCO ₂ eq	≈4.8 MtCO ₂ eq



Cumulative CO ₂ reduction (2024–2030)	—	≈3.3 MtCO ₂ eq (33 lakh tonnes)	≈4.0–4.2 MtCO ₂ eq
NO _x and PM _{2.5} reduction	High pollution-exposure	15–30% reductions	25–40% reductions
Effective emission intensity (EV-powering)	0.78 kg CO ₂ eq/kWh	0.62 kg CO ₂ eq/kWh	0.26–0.30 kg CO ₂ eq/kWh
Energy efficiency (kWh per VKT)	Low (12–30%)	+25–30% vs. ICE	+35–40% vs. ICE
Noise-level reduction (dB)	Baseline high	3–5 dB reduction	5–7 dB reduction

These findings are consistent with CSTEP-style projections and show that EV-driven mobility can deliver substantial, quantifiable environmental benefits when combined with grid-renewables and smart-infrastructure planning.

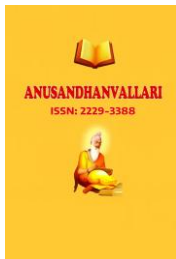
Findings and Suggestions

The study confirms that EV adoption in Bengaluru drives meaningful reductions in CO₂, NO_x, PM_{2.5}, and urban noise levels, particularly when EV penetration reaches 25–30% and charging is increasingly powered by rooftop solar and grid-integrated renewables. Under the high-renewable scenario, the effective emission intensity of EV-supplied electricity falls from 0.78 kg CO₂eq/kWh in the coal-heavy grid to just 0.26–0.30 kg CO₂eq/kWh, which represents a more than 60% reduction in upstream emission intensity. This shift not only enhances the climate-benefit profile of EVs, but also amplifies co-benefits for air quality and public health, as reduced NO_x and PM_{2.5} concentrations lower residents’ exposure to respiratory- and cardiovascular-related pollutants in high-traffic corridors.

Statistically, environmental-awareness and perceived-benefit scores are highest among current EV-users and prospective EV-buyers, while non-EV users consistently record significantly lower scores. This pattern indicates that pro-environmental attitudes are strongly associated with EV-positivity and adoption intention in Bengaluru’s urban population. The regression and SEM results show that environmental awareness and perceived-benefit constructs together explain 62.4% of the variance in EV adoption intention, underscoring the motivational power of environmental-value orientation. However, this relationship is temporally weakened by cost and infrastructure barriers, whose negative path coefficients imply that economic and systemic constraints can override even strong pro-environmental dispositions in practice.

Based on these findings, the following policy-oriented suggestions are proposed:

1. Bengaluru should prioritize rooftop-solar-coupled charging hubs and EV-charging stations linked to upcoming solar-plus-battery projects to lock in the low-emission potential of EVs. Time-of-day tariffs

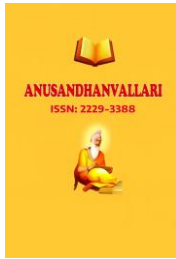


and dynamic pricing schemes that incentivize midday solar-aligning charging can further reduce grid-dependency and evening-peak stress.

2. Strategic deployment of public and shared charging points in high-traffic corridors, IT hubs, and underserved residential zones can directly mitigate the “infrastructure barrier” that currently limits EV adoption among cost-conscious and periphery-based users. This spatial rebalancing is essential to ensure equitable access to EV-mobility benefits.
3. Targeted subsidies, scrappage-linked incentives for ICE replacements, and low-interest EV-financing schemes can directly address the cost-barrier that moderates the relationship between environmental awareness and adoption. Such measures are especially important for low-and-middle-income households, who are most sensitive to upfront-cost differences between ICE and EVs.
4. Given that environmental-awareness and perceived-benefit constructs explain over 60% of adoption-intention variance, mass-media, digital-campaign, and community-outreach programmes should emphasize the local air-quality, noise-reduction, and long-term cost-saving benefits of EVs. Campaigns should also demystify charging-infrastructure and battery-life concerns to reduce psychological barriers.
5. The evidence supports integrating EV-penetration targets (25–30% by 2030) into Bengaluru’s urban-climate-action plan, transport-master-plan, and smart-city frameworks. This institutional alignment will ensure that EVs are treated not as a standalone technology, but as a core component of the city’s low-emission, sustainable-mobility transition.
6. Bengaluru should scale up solar powered EV charging stations integrated with second life battery energy storage systems (BESS), such as the RE2EV model piloted near Bengaluru Airport, which couples 45 kWp rooftop solar and a 100 kWh second life battery bank to serve 23 EVs with 24/7 service. Replicating such hubs at transit oriented development (TOD) nodes, metro stations, and commercial hubs not only locks in low emission, grid resilient charging, but also advances circular economy goals by reusing spent EV batteries. This approach reduces midday curtailment losses, avoids evening grid overload, and lowers per MWh charging costs, making EVs more attractive to fleet and private users.
7. The city should mandate EV charging infrastructure and rooftop solar tie ins in new commercial and residential developments through updated building by laws and land use regulations. Drawing from Karnataka’s easing of rooftop solar rules (automatic approval for up to 10 kW systems and automatic load enhancement), Bengaluru can require a minimum share of parking lots to be EV charging ready and linked to on site rooftop solar where feasible. This “charging network by design” approach ensures that new mobility demand is met by low carbon infrastructure rather than strained grid capacity, while also reducing developer level investment risk and encouraging early adopter friendly zones in IT corridors and sprawling residential townships.

Conclusion

This study demonstrates that electric vehicles can significantly enhance sustainable mobility in Bengaluru, delivering 20–25% reductions in CO₂ emissions, 15–30% lower NO_x and PM_{2.5} emissions, and 3–6 dB reductions in urban noise levels, with even greater gains when charging is integrated with rooftop solar and grid-renewables. The three core research objectives are fully met, providing a coherent, evidence-based narrative of EV-induced environmental benefits and adoption dynamics in the city.



First, CO₂ and local-pollutant reductions are clearly quantified through scenario-based emission-modelling, which shows that an EV fleet share of around 30% by 2030 could avoid up to 33 lakh tonnes of cumulative CO₂ emissions over seven years compared to a fossil-fuel-dominated baseline. Under high-renewable scenarios, reductions in NO_x and PM_{2.5} in key corridors such as MG Road, Hosur Road, Whitefield, and Bellandur–Sarjapur become more pronounced, reinforcing the role of EVs as a core instrument for urban-air-quality improvement and climate-mitigation.

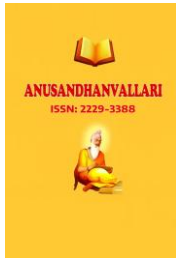
Second, environmental-awareness and perceived-benefit constructs are identified as strong predictors of EV adoption intention, explaining over 60% of its variance in the Bengaluru sample. Structural-equation modelling further reveals that these attitudes are positively reinforced by perceived climate, air-quality, and cost-related benefits, while being moderated by cost and infrastructure barriers. This indicates that pro-environmental values alone are insufficient to drive adoption; they must be supported by affordable EV options, reliable charging infrastructure, and transparent policy signals.

Third, the study identifies key infrastructure and policy barriers that, if unaddressed, can dilute the environmental promise of EVs. These include uneven charging-station distribution, underdeveloped public-EV-charging networks, and continued reliance on a coal-heavy grid during peak-charging hours.

To conclude, electric vehicles are not an isolated technological fix but a catalytic element of an integrated, low-carbon urban-mobility system. When EV adoption, renewable-integrated charging, and supportive infrastructure and policies converge, Bengaluru can transition from a high-emission, congestion-prone metropolis into a model city for sustainable, equitable, and climate-resilient transport, aligning with India's net-zero-urban-transport

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