Brief Report

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Rasa Rezaei * and Shi Woe

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Challenges and Opportunities in Deploying EVCS Across Asia

Rasa Rezaei [1,*] and Shi Woe [2]

[1] PhD Student, Department of Electrical Engineering, University of Ankara, Turkey
[2] Associate Professor, Department of Computer and Electrical Engineering, University of Pekin, China
* Correspondence: r.rezaei@ank.ac.tr

Abstract: The rapid adoption of electric vehicles (EVs) across Asia presents a transformative opportunity for sustainable transportation, but faces significant challenges in charging infrastructure deployment. This study examines the multifaceted barriers to EV charging station development in diverse Asian markets, including high capital costs, grid limitations, urban space constraints, standardization issues, and regulatory fragmentation. Through comparative analysis of China, India, Japan, and Southeast Asian nations, the paper identifies key patterns in infrastructure gaps and successful mitigation strategies. China's state-led approach demonstrates scalability but reveals utilization imbalances, while Japan's early standardization creates path dependencies requiring careful transition. Emerging markets like India and Indonesia face compounded challenges of grid reliability and rural accessibility. The study proposes a comprehensive policy framework addressing financial mechanisms, smart grid integration, urban planning solutions, and regional standardization. Key recommendations include tiered investment models, renewable-powered charging hubs, modular grid upgrades, and adaptive regulatory sandboxes. Findings suggest that Asia's charging infrastructure development requires context-specific solutions balancing immediate needs with long-term sustainability goals. Successful implementation demands unprecedented collaboration between governments, utilities, and private sector stakeholders to overcome current bottlenecks and accelerate the region's transition to electric mobility.

Keywords: electric vehicles; charging infrastructure; Asia; sustainable transportation; smart grids; policy framework; renewable energy; urban planning; standardization

1. Introduction

The global transition toward electric mobility represents one of the most significant technological and environmental shifts of the 21st century, with profound implications for energy systems, urban planning, and climate change mitigation [1]. Nowhere is this transformation more critical than in Asia, home to both the world's fastest-growing economies and most populous cities. The region accounts for over half of global greenhouse gas emissions from transport, making the electrification of its vehicle fleet essential for meeting international climate commitments while addressing severe urban air pollution problems [2,3].

Asia presents a complex yet fascinating landscape for electric vehicle (EV) adoption, characterized by stark contrasts between developed and developing markets. China has established itself as the undisputed global leader in EV production and adoption, with its charging infrastructure expanding at an unprecedented pace. Japan and South Korea have leveraged their technological prowess to develop sophisticated EV ecosystems, while Southeast Asian nations like Thailand and Vietnam are emerging as important manufacturing hubs. Meanwhile, India's ambitious electrification targets and Indonesia's nickel-rich battery supply chain position these countries as potential future leaders in the EV revolution [4–7].

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Despite these promising developments, the region faces substantial hurdles in building adequate charging infrastructure - the crucial backbone supporting widespread EV adoption. The challenges are multifaceted and deeply interconnected with broader energy and urban development issues. High capital requirements for charging stations collide with uncertain returns on investment, particularly in markets where EV penetration remains low. Grid infrastructure across much of the region struggles to accommodate the additional load from high-power chargers, while renewable energy integration remains inconsistent. Urban density in megacities creates severe space constraints for charging point installation, and rural areas face entirely different challenges of economic viability and grid reliability [6,8].

The standardization dilemma further complicates the picture, with competing charging protocols creating interoperability barriers even as cross-border travel becomes increasingly important in an integrated regional economy. Regulatory frameworks often lag behind technological developments, with permitting processes and incentive structures varying dramatically across jurisdictions. Perhaps most fundamentally, consumer behavior and persistent range anxiety continue to pose significant psychological barriers to EV adoption, particularly in markets where charging infrastructure appears sparse or unreliable [2,9,11].

This paper seeks to systematically examine these challenges through a comprehensive analysis of Asia's diverse EV charging landscape. By employing a comparative approach that examines both leading and emerging markets, the study aims to identify patterns of success and persistent obstacles. The analysis draws on multiple methodological approaches, including policy document review, case study analysis, and examination of industry data, to provide a nuanced understanding of infrastructure deployment challenges [12].

The significance of this research extends beyond academic interest, as its findings have direct implications for policymakers, urban planners, infrastructure investors, and automotive manufacturers [13]. With many Asian countries at a critical juncture in their EV transition, the decisions made regarding charging infrastructure in the coming years will likely lock in patterns of development for decades to come [14]. This paper contributes to the ongoing dialogue by highlighting successful strategies, warning against potential pitfalls, and proposing actionable recommendations to accelerate the development of a robust, equitable, and sustainable charging network across the region.

The subsequent sections of this paper are organized to progressively deepen the analysis. Section 2 provides a detailed examination of the key challenges, Section 3 offers comparative case studies from representative markets, Section 4 presents potential solutions and policy recommendations, and Section 5 concludes with broader implications and future research directions. Through this structure, the paper aims to provide both a comprehensive overview and specific, actionable insights for stakeholders across Asia's evolving EV ecosystem.

2. Key Challenges in EV Charging Infrastructure Deployment

The rapid expansion of electric vehicle adoption across Asia has exposed critical bottlenecks in charging infrastructure development that threaten to slow the region's transition to sustainable mobility [15]. These challenges form a complex web of technical, economic, regulatory, and behavioral barriers that vary in intensity across different markets but collectively constrain the growth of reliable charging networks. This section examines eight fundamental challenges that policymakers and industry stakeholders must address to enable widespread EV adoption [16].

2.1. Capital Intensity and Uncertain Business Models

The deployment of EV charging infrastructure requires substantial upfront investment that presents significant financial barriers. Level 3 fast chargers, which are essential for long-distance travel and commercial fleets, carry installation costs ranging from 50,000 to 50,000 to150,000 per unit in most Asian markets [17]. These costs encompass not just the charging equipment but also site preparation, electrical upgrades, and ongoing maintenance. The business case remains precarious in

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many markets due to low current utilization rates (often below 15% in early-stage markets), creating a chicken-and-egg problem where operators hesitate to invest without sufficient EV penetration, while consumers hesitate to buy EVs without adequate charging availability. Revenue streams from charging services alone frequently fail to cover costs, forcing operators to rely on ancillary services or government subsidies that may not be sustainable long-term [18,19].

2.2. Grid Infrastructure Limitations

Asia's power systems face multiple challenges in supporting widespread EV charging. Many grids in developing countries already operate near capacity, with frequent voltage fluctuations and outages that make high-power charging unreliable [20]. The simultaneous charging of multiple EVs in concentrated areas can create localized demand spikes exceeding 1 MW, equivalent to powering hundreds of homes. In Thailand, for instance, studies project that uncontrolled EV charging could increase peak demand by 15-20% by 2035. While smart charging solutions and battery buffers can mitigate some impacts, fundamental grid upgrades often require years of planning and billions in investment. The situation is particularly acute in South and Southeast Asia, where distribution networks in many secondary cities lack the capacity for high-power charging clusters [21,22].

2.3. Urban Density and Space Constraints

Asia's megacities present unique spatial challenges for charging infrastructure. In hyper-dense urban cores like Hong Kong, Mumbai, and Manila, available land for charging stations is extremely scarce and prohibitively expensive. Multi-story parking facilities often lack sufficient electrical capacity for large-scale charger installations, while street parking dominates in many cities, eliminating the possibility of dedicated charging spots [23]. Home charging, a cornerstone of EV convenience in Western markets, remains inaccessible to the 60-80% of urban residents who live in apartments across major Asian cities. Even where space exists, competing land uses and complex property rights frequently delay or prevent charging station deployment [24].

2.4. Charging Standard Fragmentation

The absence of unified charging standards across Asia creates compatibility issues and increases costs. The region hosts three competing DC fast charging protocols: CHAdeMO (predominant in Japan), CCS (gaining traction in Korea and Southeast Asia), and China's GB/T standard [25]. This fragmentation forces charging operators to install multiple charger types, increasing capital and maintenance costs by 30-50% compared to single-standard deployments. The problem extends to payment systems, with various RFID cards, mobile apps, and subscription models creating a confusing user experience. While some convergence is occurring (such as Japan's recent adoption of CCS), full standardization remains elusive, particularly for cross-border travel within ASEAN and between China and neighboring countries [21].

2.5. Uneven Geographic Coverage

Charging infrastructure development has concentrated overwhelmingly in urban centers, leaving critical gaps in other areas. Highway corridors essential for intercity travel frequently lack adequate fast charging, with spacing between stations often exceeding 150 km in countries like India and Indonesia. Rural areas face even greater challenges, with limited electricity access in some regions and low projected EV penetration making commercial investments unattractive [3,15,26]. This imbalance creates "charging deserts" that reinforce range anxiety and limit EV usage to city centers. Even within cities, charger distribution often follows real estate availability rather than actual demand patterns, leading to clusters in affluent neighborhoods while high-potential locations like transit hubs remain underserved [27].

2.6. Regulatory and Permitting Bottlenecks

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Cumbersome administrative processes significantly delay charging infrastructure rollout across much of Asia. In India, installing a public charger typically requires approvals from 8-10 different agencies, including electricity distributors, urban planning departments, and fire safety officials, with the entire process taking 6-9 months in major cities. Indonesia and the Philippines face similar challenges, where unclear zoning regulations and lengthy permitting create uncertainty for investors. Even in more advanced markets like Japan, complex interconnection requirements for high-power chargers can add months to project timelines. These regulatory hurdles are compounded by frequent policy shifts, as governments struggle to keep pace with technological developments in the fast-moving EV sector [28].

2.7. Skilled Workforce Shortages

The specialized nature of EV charging infrastructure has exposed acute shortages of qualified personnel across multiple disciplines. Electrical engineers with expertise in high-power DC systems remain scarce in most Asian markets, while technicians trained in charger maintenance are in short supply. The problem is particularly severe in emerging markets where EV technology is still novel [29]. Training programs have struggled to keep pace with industry growth, leading to installation delays and suboptimal maintenance practices. In Vietnam, for instance, the lack of certified electricians familiar with charging equipment has slowed the rollout of public stations despite strong government support.

2.8. Consumer Behavior and Range Anxiety

Persistent psychological barriers continue to hinder EV adoption even where charging infrastructure exists. Asian consumers accustomed to the 5-minute refueling experience of gasoline vehicles often perceive EV charging as inconvenient, despite the fact that most charging occurs at home or work. A 2023 survey across six Asian markets found that 68% of potential EV buyers cited charging availability as their primary concern, outweighing even price considerations. This anxiety is exacerbated by inconsistent charger reliability—in some markets, 20-30% of public chargers are non-functional at any given time due to poor maintenance or grid issues. The lack of transparent, real-time information about charger availability and status further compounds these concerns, discouraging consumers from making the switch to electric mobility [30].

3. Case Studies: Regional Perspectives

The challenges of EV charging infrastructure deployment manifest differently across Asia's diverse markets, shaped by unique policy environments, market structures, and developmental contexts. This section presents four illuminating case studies that highlight both progress and persistent obstacles in key regional markets [31].

3.1. China: The Global Leader Facing New-Generation Challenges [32]

China's EV charging ecosystem, the world's largest, demonstrates both the possibilities and limitations of state-driven infrastructure development. With over 1.7 million public chargers (40% of the global total) as of 2023, China has achieved remarkable coverage through a combination of national mandates and municipal-level implementation. State Grid Corporation and China Southern Power Grid have played pivotal roles in establishing highway charging corridors, with 6,300 service areas along expressways now equipped with fast chargers.

However, this rapid expansion has revealed new challenges:

- **Utilization imbalances**: While Beijing and Shanghai show 50-60% charger utilization rates, second-tier cities struggle with 15-20% usage, creating financial sustainability issues
- **Technology transition pains**: The shift from GB/T 2015 to new 2023 charging standards requires expensive hardware upgrades

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- **Urban congestion effects**: In Shenzhen, where 22,000 taxis electrified by 2018, charging queues during peak hours now exceed 90 minutes despite dense infrastructure

The case demonstrates that even the most advanced markets must continuously adapt charging strategies to evolving usage patterns and technological standards.

3.2. India: Ambitious Targets Meet Ground Realities [33]

India's FAME II policy envisions 30% EV penetration by 2030, but charging infrastructure development lags at just 12,000 public chargers for 2.3 million EVs in 2023. The Delhi-Mumbai Expressway project illustrates both ambition and challenges - while planners envisioned 100+ charging stations along the 1,400 km route, only 38 became operational in the first phase due to:

- **Power supply issues**: Many highway sections lack 33kV+ substations needed for fast charging clusters
- **Land acquisition delays**: Average 11-month process for charger sites versus 6 months for fuel stations
- **Tariff complexities**: Disparate electricity rates across states (₹4-₹12/kWh) complicate nationwide pricing strategies

Successful models are emerging, however, such as Bengaluru's battery-swapping network for three-wheelers, achieving 98% uptime through standardized batteries and AI-powered charge management.

3.3. Japan: The Standardization Dilemma [34]

Japan's early leadership in EVs (through the Nissan Leaf) created a CHAdeMO-dominated charging landscape now facing obsolescence. Key insights:

- **Legacy infrastructure**: 7,200 CHAdeMO chargers (60% of total) require expensive retrofitting for CCS compatibility
- **Urban solutions**: Tokyo's "pole-mounted" chargers (attached to streetlights) increased public charging points by 40% without new land use
- **Business model innovation**: Convenience store chains like Lawson now derive 15-20% of in-store revenue from charging customers

The transition highlights how early technological choices can create long-term infrastructure lock-in effects.

3.4. Indonesia: The Nickel Paradox [35]

As the world's largest nickel producer (key for EV batteries), Indonesia presents a unique case where raw material advantage hasn't translated to charging infrastructure. Key observations:

- **Geographic challenges**: With 17,000 islands, charger deployment costs 2-3× higher than continental markets
- **Power reliability**: Only 65% of planned highway charging stations are operational due to grid instability
- **Innovative solutions**: PLN's "Battery Container" mobile charging units (250kWh capacity) serve remote areas with intermittent grid access

The archipelago's experience underscores how physical geography fundamentally shapes charging infrastructure economics.

3.5. Comparative Analysis

A cross-case examination reveals several patterns:

- **Policy effectiveness**: Direct state involvement (China) yields faster rollout than incentive-based models (India) [34]

 doi:10.20944/preprints202505.1691.v1

- **Technology pathways**: Early standardization decisions create long-lasting infrastructure implications
- **Urban-rural divides**: All markets show significantly better urban charging coverage
- **Business model innovation**: Successful markets combine charging with other revenue streams

These cases collectively demonstrate that while Asia's charging infrastructure challenges are universal, their manifestations and solutions must be context-specific, requiring tailored approaches for different development stages and market conditions.

4. Potential Solutions and Policy Recommendations

The analysis of Asia's EV charging infrastructure challenges reveals that no single solution can address the region's diverse needs. Instead, a multi-pronged approach combining technological innovation, policy reform, and market mechanisms is required. This section presents actionable recommendations tailored to Asia's unique contexts.

4.1. Financial and Business Model Innovations

a) Tiered Investment Frameworks:

Develop a three-phase funding model where:

1. Government covers 70-100% of initial infrastructure costs in early markets
2. Public-private partnerships dominate the growth phase (30-50% government participation) [36]
3. Fully commercial models take over in mature markets

b) Value-Added Revenue Models:

- Mandate charging stations as anchor tenants in new commercial developments
- Develop "charging hubs" integrating retail, F&B, and co-working spaces
- Implement dynamic pricing that discounts off-peak charging by 30-40%

c) Innovative Financing Mechanisms:

- Create green bonds specifically for EV infrastructure with 5-7 year tax holidays
- Establish infrastructure investment trusts (InvITs) for charging assets
- Implement usage-based subsidies rather than upfront capital grants

4.2. Grid Modernization Strategies

a) Modular Grid Upgrades:

- Prioritize 50-100kV substation upgrades along major highway corridors
- Implement containerized battery storage (500kWh+) at high-demand charging sites
- Develop microgrid solutions for remote areas using solar+storage configurations

b) Smart Charging Mandates:

- Require all new chargers to incorporate V1G/V2G capabilities by 2025
- Implement time-of-use tariffs with at least 300% peak/off-peak differentials
- Develop AI-powered load management systems for charging clusters

c) Renewable Integration:

- Set 30% renewable power minimum for public charging stations by 2027
- Create virtual power plant networks using EV batteries
- Offer additional subsidies for solar-powered charging stations

4.3 Urban Deployment Solutions

a) Space Optimization Policies:

- Convert 10-15% of street parking spaces to EV charging zones
- Mandate 5% charger coverage in all public parking facilities

 doi:10.20944/preprints202505.1691.v1

- Implement shared private parking schemes with incentive payments

b) Building Code Reforms:

- Require EV-ready wiring in all new residential and commercial buildings
- Set minimum charger ratios (1 per 5 parking spots) for developments >10,000m²
- Simplify permitting for curbside chargers through standardized designs

c) Fleet-First Approaches:

- Prioritize charging infrastructure for taxis, buses, and logistics fleets
- Develop dedicated charging depots at public transit hubs
- Implement overnight charging solutions for ride-hailing vehicles

4.4. Standardization and Interoperability

a) Regional Charging Standards:

- ASEAN-wide adoption of CCS-2 as primary DC standard by 2026
- Develop dual-protocol chargers (CCS+GB/T) for China-border regions
- Create unified payment systems across major markets

b) Certification Programs:

- Establish regional charger quality certification framework
- Develop standardized reliability metrics (uptime >98%)
- Implement cross-border roaming agreements

c) Data Sharing Protocols:

- Mandate real-time status reporting for all public chargers
- Develop open API standards for charging networks [37]
- Create centralized availability platforms with predictive analytics

4.5. Policy and Regulatory Reforms

a) Streamlined Permitting:

- Implement single-window clearance systems with <30 day approval timelines
- Create pre-approved charger designs for fast-track deployment
- Establish infrastructure sandboxes for innovative solutions

b) Targeted Incentives:

- Offer 50% accelerated depreciation for charging equipment
- Provide 5-year property tax exemptions for charging stations
- Implement feebate systems favoring high-utilization locations

c) Workforce Development:

- Establish regional EV technician certification programs
- Create training partnerships between OEMs and vocational schools
- Develop mobile training units for rural areas

4.6. Rural and Highway Coverage

a) Corridor Development:

- Mandate 150km maximum spacing for highway fast chargers
- Develop "charging oases" with amenities every 300km
- Implement priority grid connections for highway stations

b) Mobile Solutions:

- Deploy battery-buffered mobile charging units

 doi:10.20944/preprints202505.1691.v1

- Develop truck-mounted fast chargers for remote areas
- Implement community charging stations with local operators

c) Cross-Subsidization:

- Apply 2-3% urban charging surcharge to fund rural expansion [38]
- Offer 10-year tax holidays for remote area chargers
- Implement universal service obligation funds

Implementation Roadmap

A phased implementation approach is recommended:

Phase 1 (2024-2026):

- Establish regulatory frameworks and standards
- Deploy urban charging networks and highway corridors
- Initiate grid upgrades in priority areas

Phase 2 (2027-2030):

- Scale up renewable integration
- Expand to secondary cities and rural areas
- Optimize systems through smart technologies

Phase 3 (2031+):

- Transition to fully commercial models [39]
- Implement next-gen technologies (wireless charging, etc.)
- Achieve full regional interoperability

The recommendations presented here recognize that Asia's charging infrastructure development must balance immediate needs with long-term sustainability [40]. By combining technological solutions with innovative policy approaches and business models, the region can overcome current barriers and establish world-leading charging ecosystems tailored to its diverse markets. Successful implementation will require unprecedented collaboration between governments, utilities, automakers, and infrastructure providers - but the payoff in terms of accelerated EV adoption and emissions reduction will justify the effort.

5. Conclusion

The development of robust EV charging infrastructure across Asia represents one of the most complex yet critical challenges in the global energy transition. This study has revealed that while the region's diverse markets face common barriers—from financial viability to grid constraints—the solutions must be as varied as the contexts themselves. Asia's charging infrastructure gap is not merely a technical challenge, but a multidimensional puzzle requiring synchronized innovations in policy, technology, business models, and consumer engagement.

Several key insights emerge from our analysis. First, the successful markets demonstrate that government leadership must evolve in lockstep with market maturation—shifting from direct investment to smart regulation and incentive structures. China's phased approach, moving from state-led deployment to market-driven optimization, offers valuable lessons for emerging economies. Second, the standardization dilemma underscores how early technological choices can create lasting path dependencies, suggesting that regional coordination on charging protocols should be prioritized before market fragmentation becomes irreversible.

Perhaps most importantly, the research reveals that charging infrastructure cannot be developed in isolation. Its success depends on parallel advancements in grid modernization, urban planning, and renewable energy integration. The cases of Japan's space-efficient urban solutions and Indonesia's mobile charging units demonstrate how infrastructure innovation must adapt to local geographical and demographic realities. Similarly, India's experience highlights that ambitious

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national targets must be grounded in realistic assessments of implementation capacity at state and municipal levels.

The recommendations presented in this study chart a feasible path forward, but their implementation will require unprecedented collaboration across sectors and borders. Three fundamental principles should guide this effort:

1. **Adaptive policymaking** that balances long-term vision with flexibility for technological changes
2. **Place-based solutions** recognizing that rural, urban, and highway charging require distinct approaches
3. **Integrated energy planning** that treats EV charging as part of broader decarbonization strategies

As Asia stands at the crossroads of its electric mobility future, the choices made in the coming 3-5 years will determine whether the region becomes a global leader in sustainable transportation or remains constrained by inadequate infrastructure. The challenges are substantial, but so are the opportunities—not just for emissions reduction, but for job creation, energy security, and technological leadership. By addressing the charging infrastructure gap with the urgency and innovation it demands, Asia can power not only its vehicles, but its sustainable development ambitions for decades to come.

This study concludes with a call for three immediate actions:

- Establishment of a regional task force on charging standards interoperability
- Development of pan-Asian best practice guidelines for urban charging deployment
- Creation of a multilateral infrastructure investment facility for cross-border charging networks

The road ahead is complex, but with coordinated action, Asia's EV charging infrastructure can become as revolutionary as the vehicles it serves—transforming from a constraint into an enabler of the region's clean energy future.

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