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Building Resilient EV Charging Networks with Edge Intelligence

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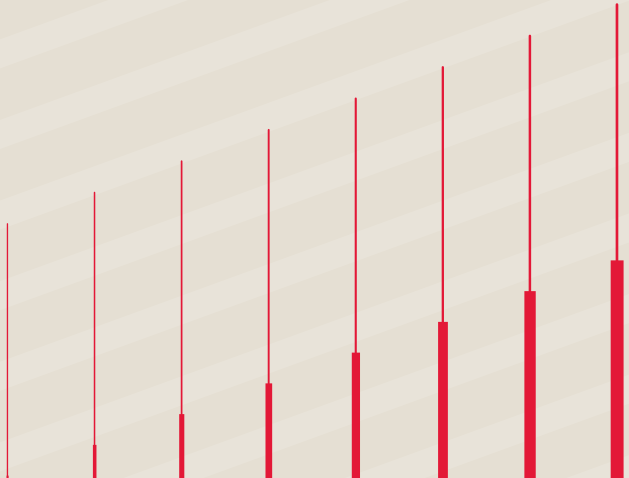
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Executive Summary

Over the next decade, there will be an influx of electric vehicle (EV) adoption globally. While this major shift contributes positively to carbon neutrality, it also marks a monumental change in how humanity consumes power. According to the International Energy Agency (IEA), electric mobility is one of the key drivers that will significantly increase electricity demand by 2030.[1]

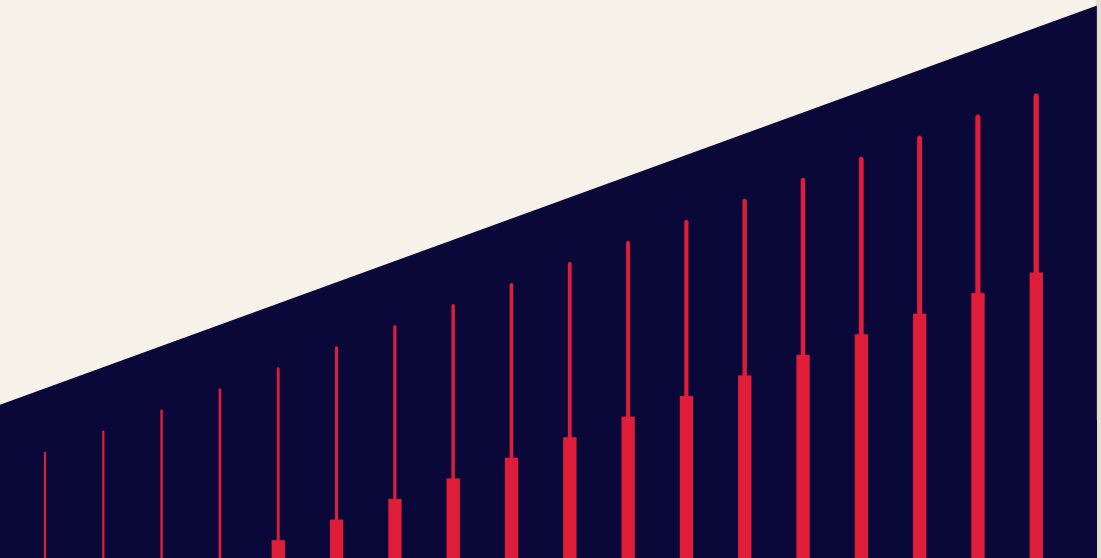
Amidst these developments, EV charging is introducing a new set of challenges to grid management, power distribution, and demand planning. Traditionally, electricity demand largely follows consumer usage patterns. EV charging demand, on the other hand, depends on time-sensitive and site-specific factors.

As changing charging patterns test the capacity of energy infrastructure, effectively anticipating and managing power demand becomes extremely critical. Drawing on these emerging requirements, the following exploration examines the bottlenecks of conventional EV charging and presents an edge-enabled EV approach to address them.



The Reality of Conventional EV Charging

In view of the attention EVs have received of late, it is easy to think that conventional charging infrastructure is equipped to support their growing adoption. However, evolving charging requirements, shifting consumer behavior, and the skewed nature of power demands complicate energy management, leading to unintended peaks and supply shortages.



Currently, most EV charging infrastructure operates through centrally controlled management systems. These systems are often geographically distant from the chargers, creating several operational challenges, such as:

- Limited visibility of site-level constraints
- Delayed response to site-based electrical conditions
- Dependence on continuous network availability
- Increased stress on electrical equipment

As charging stations expand across apartments, office buildings, depots, and other prime locations, site-level constraints are becoming increasingly evident. Additionally, as these stations simultaneously draw more power from the same distribution network, inadequate load handling and coordination hurdles are further complicating power management.

Edge-Based EV Charging:

The New Frontier for Power Management

To enable real-time intelligent demand management and optimize charging operations, providers need to embed edge-enabled AI capabilities directly into the charging stations. This approach ensures that autonomous decision-making occurs in the vicinity of the charging infrastructure, minimizing dependence on centralized systems. With this localized approach, charging stations can respond to any on-site condition at any time.

An edge-based EV charging model encompasses:

- Integrated chargers with edge intelligence
- Near-real-time power optimization capabilities
- Secure charging capabilities during network connectivity issues



Under this model, vehicles can charge faster when electricity demand is low, and when the charging station or distribution network is under stress, power can be optimized to protect the network and its electrical assets.

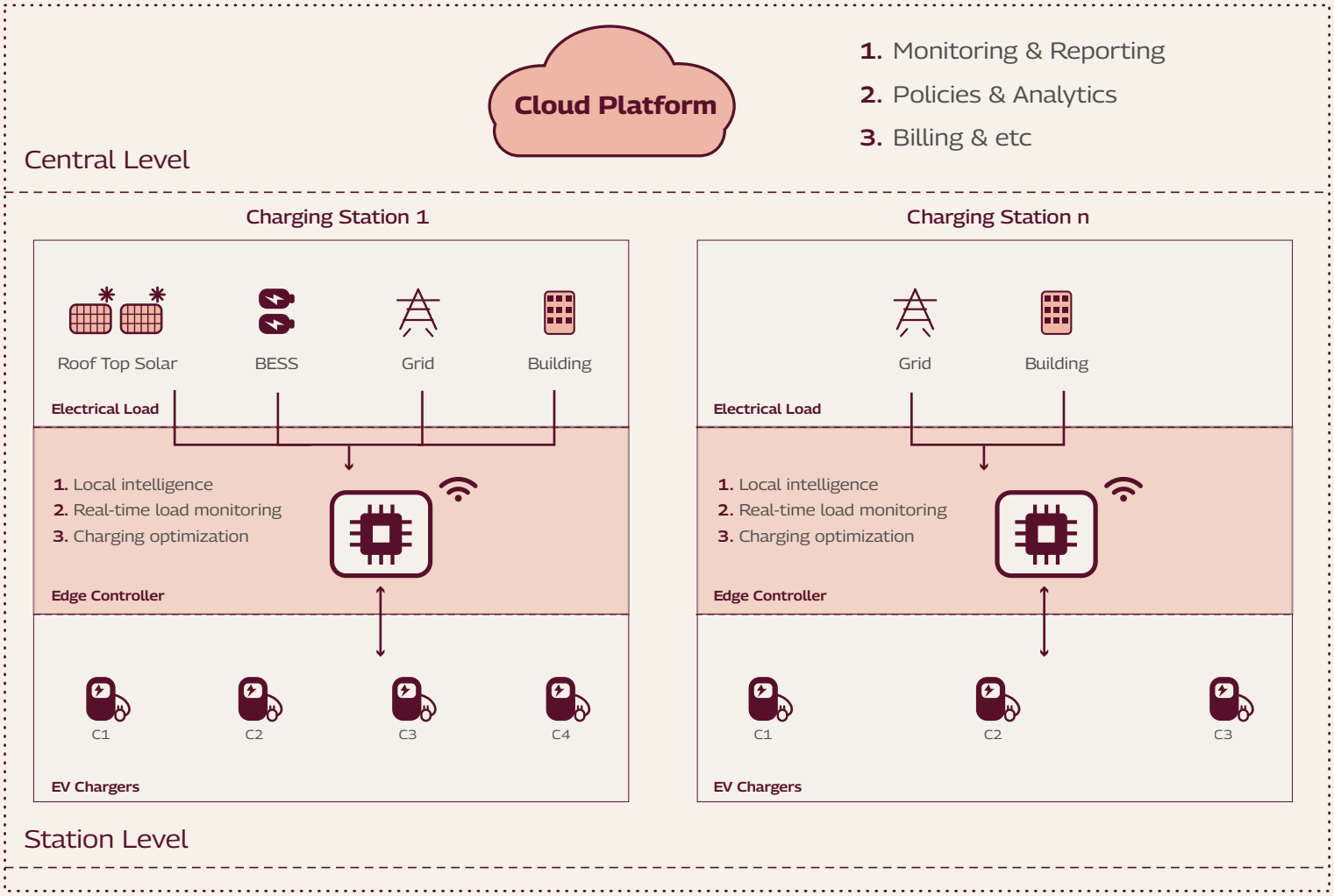


Figure 1: Overview of an Edge-Enabled EV Charging Station

Smarter EV charging starts at the site, where power availability and charging demand need to be managed in real time.

The Role of Digital Systems in Enabling Edge-Based Charging

The proposed charging model integrates digital technologies, including edge computing, IoT, AI-driven predictive modeling, and advanced analytics. By using these technologies, stations connect chargers, electric meters, and other local assets to an edge-based control system for monitoring and decision-making.

The model unifies these technologies for:



Real-time data monitoring



Optimization of charging decisions



Site-level synchronization of charging requests across multiple units



Reporting and notification to the central management system

Collectively, these capabilities create a localized decision loop at the charging site. The model then uses local data to assess electrical conditions, coordinate charging requests, and adjust charging decisions based on site-level demand.

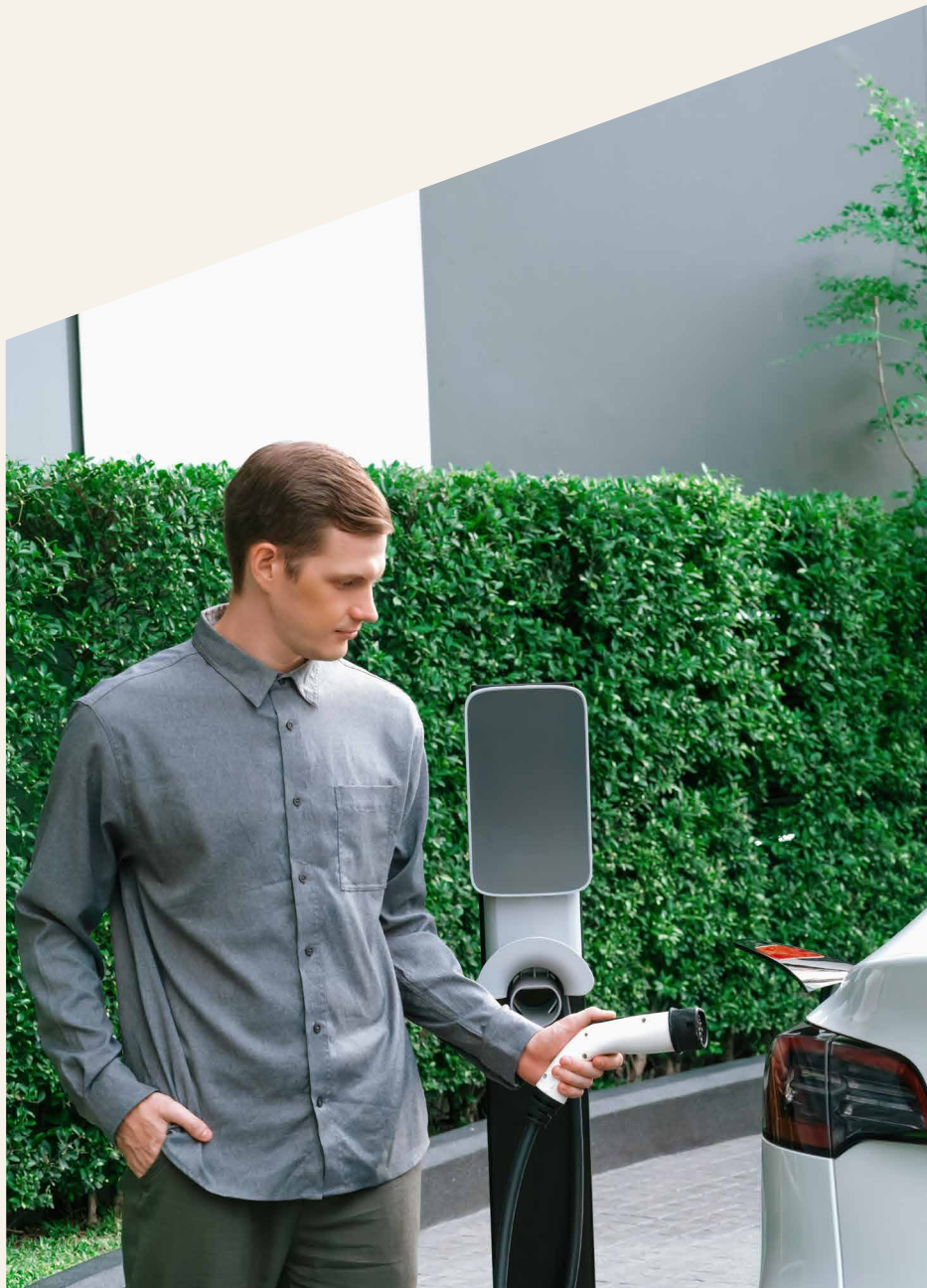
Scaling Edge-Enabled Charging Across the EV Ecosystem

Beyond managing power demands at individual charging stations, edge-based EV solutions provide extended value across various charging environments. The solution helps manage situations where EV charging demand exceeds the capacity of local distribution grids.

The solution implementation is beneficial across:

- Residential apartments
- Office buildings
- Highway charging stations
- Fleet operations centers, logistics hubs, and storage facilities

Consider an office building or an older apartment complex. These legacy structures were not built to handle the immense load of 20 electric vehicles plugging in all at once. In such cases, the electrical demand far exceeds the local grid's physical capacity. By integrating intelligence at the edge, the solution enables the safe installation of more chargers and helps service more vehicles in high-traffic, physically constrained locations. Additionally, it enables charging infrastructure to scale while reducing stress on existing assets.



Operational Benefits and Key Implementation Challenges

The IEA's global EV outlook predicts that electric four-wheelers will make up a staggering 40% of new vehicle sales by 2030.[2] With this expansion in place, charging networks will need to accommodate the growing demand while operating within the limits of the distribution networks. Edge-enabled EV facilities can help balance these requirements.

Capability	Impact
Enhances Grid Reliability	Minimizes the overloading risks on local distribution networks
Ensures Reliable Charging	Supports uniform charging, even under varying conditions
Optimize Power Availability	Distributes available power across all connected chargers
Reduces Costly Upgrades	Helps make the most out of existing capacity and assets
Accelerates Deployment	Aids in new installation of chargers and expansion of EV facilities
Decreases Operational Risks	Anticipates charging disruptions and helps reduce equipment stress
Augments Customer Experience	Provides consistent charging experience for users

Table 1: Advantages of an Edge-Enabled EV Charging System

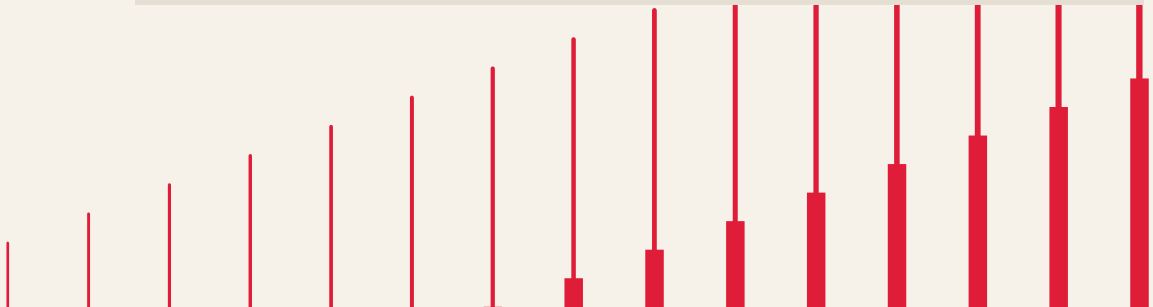
Despite these benefits, deploying edge-based EV charging stations can also introduce the following challenges.

Uncertain Power Capacity:

Edge-enabled EV charging requires accurate visibility into site capacity to make local charging decisions. However, power availability at most charging sites often varies due to shared building loads and seasonal demand fluctuations. This variability can complicate allocation, leading to breaker trips, transformer stress, and inconsistent charging experiences.

Multi-Vendor Integration Complexity:

Edge-enabled EV charging environments may use equipment from multiple manufacturers with different operational characteristics. Under throttling, restarts, or degraded power conditions, these differences can cause session drops, stalled charging states, and increased operational and maintenance effort.



Tech Mahindra's Strategic Roadmap for Edge-Based EV Charging

Transforming charging networks with an edge-enabled approach requires a structured, phased implementation across sites and operations. Tech Mahindra supports this progression through solution design and execution support.

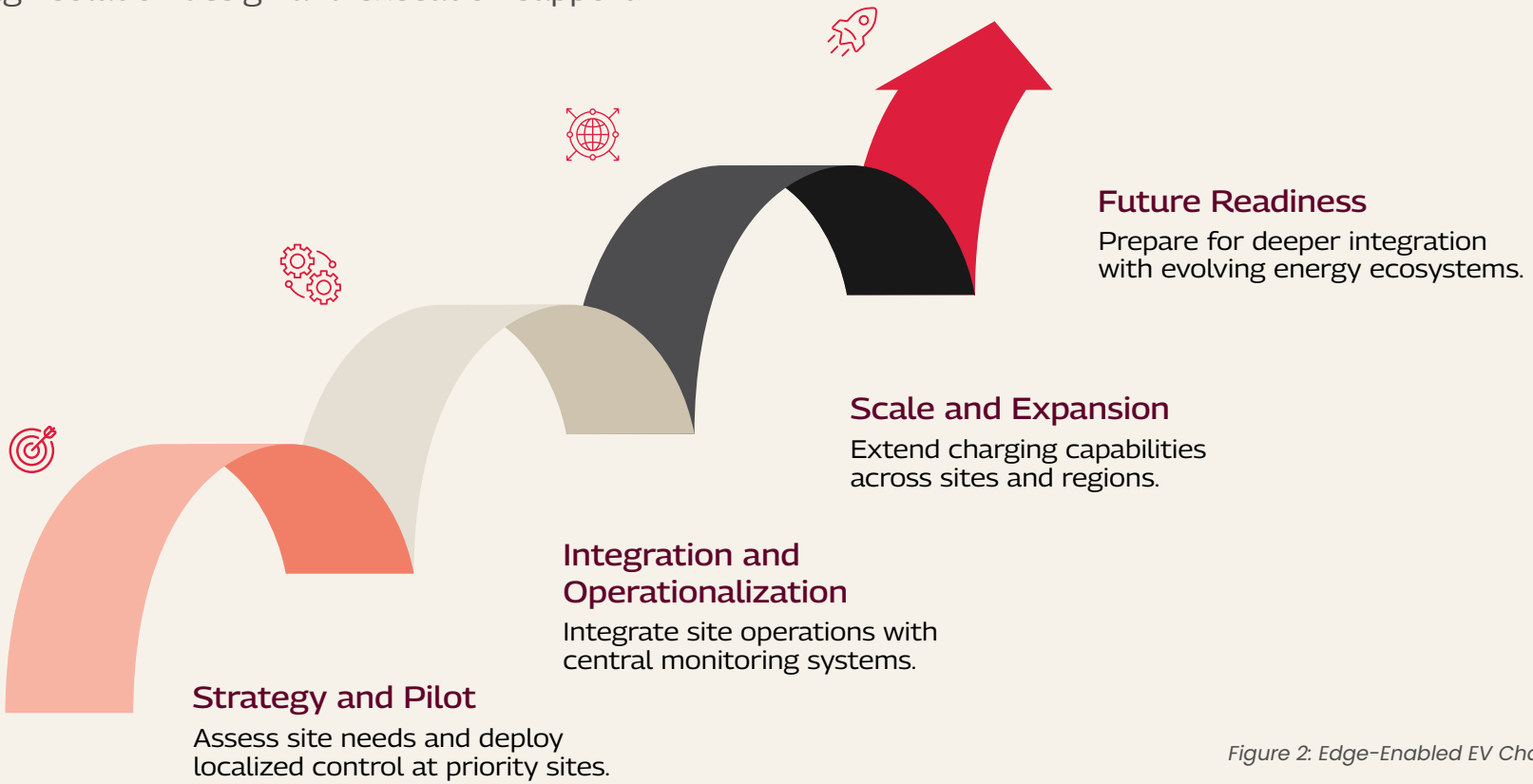


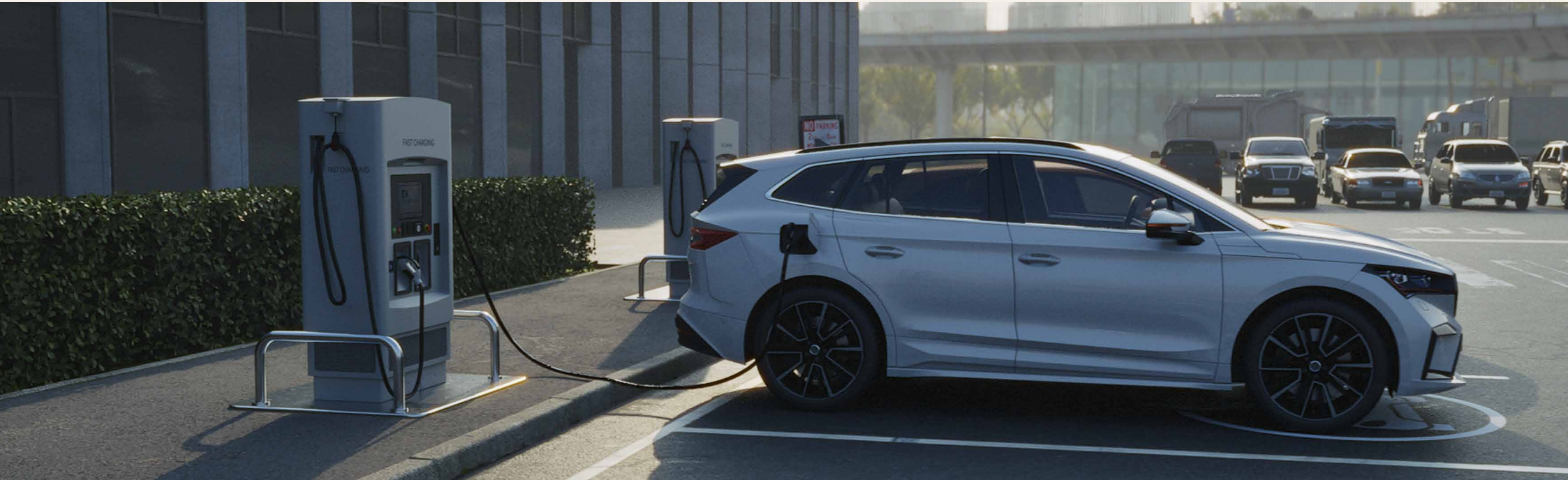
Figure 2: Edge-Enabled EV Charging Adoption Roadmap

In addition to deployment, Tech Mahindra also provides ongoing support through Edge-Enabled EV Charging-as-a-Service. This helps operators establish and manage intelligent charging stations with real-time site monitoring, automated load management, and centralized visibility across operational sites.

The Final Word

As EVs drive the next wave of mobility, effective charging management becomes imperative. Edge-enabled EV charging management emerges as a scalable approach that brings decision-making closer to the point of demand, helping operators manage power, improve reliability, and support network growth.

The next phase of EV expansion requires charging infrastructure that is not only functional but also intelligent, adaptive, and responsive. With Tech Mahindra's end-to-end edge-enabled charging support, utilities, smart cities, and charging operators can build resilient EV charging ecosystems aligned with their local needs and long-term electrification goals.



About the author

Dinesh is a Smart Energy Management Solution Lead at Tech Mahindra within the Energy and Utilities Vertical Practice. In this role, he is responsible for developing domain-specific smart energy management solutions and building a strong partnership ecosystem. Dinesh brings over 14 years of domain experience, including five years in thermal power plants and continuous process industries.



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