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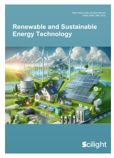

Article

Electric Vehicle Charging Infrastructure Trends Costs and Policy Impacts in the UAE

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How To Cite: Abokhalil, A.G. Electric Vehicle Charging Infrastructure Trends Costs and Policy Impacts in the UAE. *Renewable and Sustainable Energy Technology* **2026**, *2*(1), 5. https://doi.org/10.53941/rset.2026.100002

Received: 11 January 2026
Revised: 12 February 2026
Accepted: 25 February 2026
Published: 6 March 2026

Abstract: The rapid growth of electric vehicle (EV) adoption has intensified the need for scalable, reliable, and strategically planned charging infrastructure, particularly in emerging EV markets such as the Gulf Cooperation Council (GCC) region. While prior studies often focus on policy targets and infrastructure deployment statistics, limited research evaluates infrastructure adequacy relative to adoption growth and long-term sustainability objectives. This study develops a mixed-method analytical framework that integrates longitudinal EV sales data (2015–2025), charger deployment statistics, charger-to-vehicle ratio analysis, policy evaluation, and techno-economic comparison of AC and DC charging systems. The United Arab Emirates (UAE) is examined as a regional case study using official datasets from international agencies and national authorities. The results indicate that although EV sales have expanded rapidly, infrastructure deployment has experienced periods of lag, reflected in declining charger-to-vehicle ratios before recent stabilization through anticipatory planning aligned with the UAE Net Zero 2050 strategy. The study further demonstrates that balanced integration of slow and fast charging technologies, supported by coordinated public–private partnerships and regulatory reform, is critical to ensuring infrastructure adequacy, user confidence, and grid stability. By distinguishing descriptive reporting from structured analytical evaluation, this research contributes a transferable assessment framework for EV infrastructure planning in rapidly developing energy-transition economies. The findings provide policy-relevant insights for sustainable transport electrification across the GCC region.

Keywords: electric vehicles; EV charging infrastructure; fast charging; sustainable transportation; UAE green mobility

1. Introduction

1.1. Motivation and Context

Domestically and internationally, environmental pollution caused by fine dust and greenhouse gas-induced global warming due to climate change has reached a socially critical level. Following the 2015 Paris Climate Agreement, regulations on pollutants and restrictions on vehicle emissions have been strengthened, with increasing environmental regulations in the automotive sector now being codified into law. Currently, with the shift in the energy paradigm, energy sources are transitioning from raw materials such as coal and oil to electricity generated from solar power, solar thermal energy, wind, geothermal, and hydro power. This electricity is now stored using Energy Storage Systems (ESS). Alongside this transition, global sales of electric vehicles are on the rise [1].

The automotive market has been facing challenges such as the depletion of fossil fuels, global warming, and increasingly stringent environmental regulations. As a result, eco-friendly vehicles—particularly electric vehicles

(EVs)—are gaining attention as alternatives. In response to these changes, many countries are actively promoting EV adoption through policy support and incentives. The EV market is growing rapidly. As of now, EV sales are increasing steadily, and the scale of the market is expanding. With the onset of the COVID-19 pandemic, interest in cleaner energy and sustainability has grown globally, further accelerating the shift toward EVs [2].

The Electric Vehicle Outlook report by Bloomberg New Energy Finance presents long-term forecasts and trends for electric vehicles over a 20-year span through 2040 [3]. The report projects that by 2040, about half of all newly sold vehicles will be battery electric vehicles (BEVs), followed by internal combustion engine (ICE) vehicles and plug-in hybrid electric vehicles (PHEVs). It is expected that over 57% of passenger vehicles sold by 2040 will be electric [4].

A Battery Electric Vehicle (BEV) is powered solely by electricity and produces no fine dust emissions, making it a zero-emission vehicle. To promote the widespread adoption of electric vehicles, a variety of charging infrastructure models are being implemented. These include public charging stations installed in frequently accessed public areas like parking lots, as well as residential apartment complex charging stations intended for residents [5].

Global EV sales have been growing exponentially, supported by declines in battery costs and increasing model availability. Annual EV sales increased from ~0.5 million (2015) to ~11.0 million (2023) and are projected to reach ~16.0 million (2025), while the public charger stock grew from ~1.0 million (2015) to ~3.2 million (2023) and is expected to reach ~5.0 million (2025). Figure 1 illustrates these trends, showing annual global EV sales surging alongside the cumulative number of public charging points. Despite an average annual growth rate over 100% in both EV sales and charger installations during 2015–2025, charging infrastructure rollout must continue expanding to support the accelerating EV adoption rate.

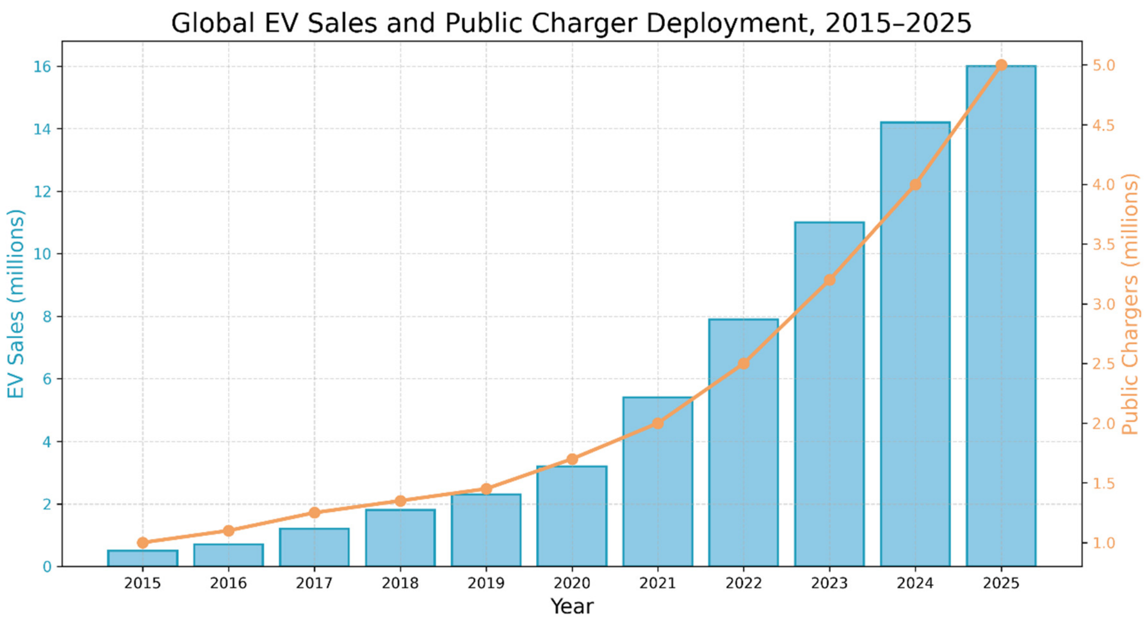

Figure 1. Global EV sales (annual, bars) and public charger stock (cumulative, line), 2015–2025.

Charging infrastructure is essential for EVs. As various charging environments and methods are introduced, users are becoming increasingly interested in charging speed, cost, convenience, and location. The development of charging infrastructure technology now focuses on improving user experience and ensuring compatibility across systems. Reducing charging times, ensuring safety, and improving convenience are key technological challenges [6].

In practice, EVs that travel up to 300 km on a full charge require about 8 h for full charging using 200 V batteries, or 1–2 h with a 400 V fast charger. However, these times can vary depending on battery capacity and charger type. As charging needs grow more diverse, advanced charging technologies are required [7]. Compared to traditional internal combustion engine vehicles, electric vehicles still face technical limitations such as shorter driving ranges, limited charging station availability, and longer charging times. Without a sufficient charging infrastructure in place, it is difficult to accelerate the widespread adoption of electric vehicles. However, considering the high installation costs of chargers, indiscriminately deploying them in large numbers would be economically inefficient. It could reduce user convenience and lead to unnecessary waste of government and municipal budgets [8].

1.2. Literature Review

Understanding the driving and charging behavior of electric vehicle (EV) users is essential not only for expanding EV supply but also for efficiently utilizing power system resources. For this reason, many domestic and international studies have focused on EV user behavior related to driving and charging patterns. Research has particularly examined factors influencing charging behavior, including decision models and location choice models. However, many of these studies have relied on assumptions about rational decision-making rather than actual data on user behavior, making them limited in reflecting real-world conditions [9].

Some prior studies attempted to estimate charging demand by applying hypothetical costs or average driving distances, while others focused on optimizing infrastructure placement without reflecting actual charging behavior. Although a few studies explored the potential of V2G (Vehicle-to-Grid) by estimating charging demand based on power system needs, they lacked a basis in real-world behavioral data. A common limitation among these prior studies is that they used transportation and charging data that was either generalized or based on limited simulations, without accounting for specific behavioral characteristics of EV users. In some cases, assumptions were made based on vehicle specifications alone, which does not accurately reflect user choice behavior in real environments [10]. Therefore, the main objective of this study is to analyze the actual driving and charging behavior of EV users using empirical survey data. By incorporating survey responses and real-time data from domestic EV users, this study aims to reflect actual decision-making conditions in scenarios such as V2G application and charging infrastructure utilization.

(1) Analyzed data from a survey of plug-in electric vehicle (PEV) owners, comparing the ratio of gasoline to electric vehicle miles traveled per day (eVMT). The study used regression models and simulations to determine what factors most influenced eVMT. It concluded that EVs tend to be driven until fully depleted before recharging, and that users maximize their electric mileage (eVMT) before switching to gasoline. Based on this, it was suggested that users charge EVs only when the battery is nearly empty due to concerns about charging infrastructure availability.

(2) Analyzed data from the "BEV usage trial" project to understand time-of-day charging patterns and the impact of fast vs. slow charging availability. The study applied a mixed logit model to explore EV user preferences for different charging scenarios such as:

- "Charge immediately upon arrival"
- "Charge later"
- "Charge at another location"
- "Do not charge"

The study showed that user intent (e.g., trip purpose or destination) strongly affects charging choices, but its conclusions were limited due to the simplified classification of charging alternatives.

(3) Analyzed charging behavior based on data from Jeju Island and concluded that the current approach of expanding infrastructure by simply adding more fast chargers is inefficient. Instead, he emphasized that optimal placement strategies for both slow and fast chargers should consider vehicle behavior and user preferences. He also highlighted the importance of user-specific charging behavior analysis for improving infrastructure operation efficiency.

(4) Studied factors influencing EV users' charging behavior, especially focusing on charging location choice and installation of home chargers. He found that users' choice of charger is highly influenced by SoC (State of Charge), vehicle ownership type, and availability of residential parking. He also emphasized the growing importance of Home Chargers in user decision-making, indicating that personal circumstances like home ownership and job location significantly influence charging behavior.

(5) Classified EV users into groups based on demographic and travel characteristics and explored their charging preference behavior using a binary logit model. Results showed that minimum acceptable SoC varied by group, and vehicle type, travel distance, and availability of fast chargers all played critical roles in determining charging decisions.

(6) Applied a binary logit model to analyze factors influencing user selection of EV charging stations. Using a stated preference (SP) survey, the study identified key variables such as price, distance, and charger type. Another study using a latent class model also emphasized the importance of charger availability and convenience over cost.

(7) Focused on whether EV users fully charge or only partially charge at public stations. It highlighted that frequent partial charging is more common among EV owners without private chargers. It also found that State of Charge (SoC) at arrival and trip purpose significantly affect the choice to fully or partially charge. This research provides important insight into the impact of charging patterns on public infrastructure demand.

(8) Conducted a study using 400 EV users, tracking their charging behavior over one year. He found that users generally charge at specific times and locations, with preferences highly influenced by weekday/weekend differences and battery level at arrival. The study also found that users prefer not to charge to 100% unless planning a long trip.

(9) Developed a model to estimate charging demand by time period and compared it with photovoltaic (PV) generation output. He simulated charging scenarios under various vehicle SoC levels and random charging patterns, finding that a 45% random usage rate was realistic. He suggested that better estimates of charging demand can be achieved by accounting for economic incentives and behavioral factors, especially in subsidy-related studies [11,12].

1.3. Research Contribution and Paper Organization

Despite extensive literature on EV adoption and charging behavior, limited studies provide a structured analytical assessment of infrastructure adequacy relative to adoption growth within emerging GCC markets. This study contributes by integrating longitudinal infrastructure data, charger-to-vehicle ratio evaluation, techno-economic cost comparison, and policy assessment within a unified framework, using the UAE as a representative fast-follower case.

Electric vehicles still face shorter driving ranges and longer "refueling" times compared to conventional cars, making the availability and efficiency of charging infrastructure a critical factor for consumer acceptance. Without sufficient charging facilities, range anxiety and inconvenience could stall EV adoption. At the same time, indiscriminate deployment of chargers without regard to utilization can be economically inefficient. Effective planning must therefore balance coverage and cost: deploying enough chargers to reassure drivers, but in a strategic way that optimizes usage and investment.

Although several studies have examined electric vehicle adoption trends and charging infrastructure deployment within the GCC region, much of the existing literature remains primarily descriptive, focusing on policy targets, announced infrastructure projects, and projected market growth. In contrast, the present study contributes novel analytical insights by moving beyond static reporting toward a dynamic assessment framework.

First, this study evaluates infrastructure adequacy through longitudinal analysis of charger-to-vehicle ratios, enabling assessment of whether infrastructure expansion has proportionally matched EV penetration growth. This temporal evaluation provides a more rigorous measure of planning effectiveness than absolute charger counts alone. Second, the study introduces a conceptual distinction between reactive and anticipatory deployment strategies, demonstrating how UAE infrastructure planning has evolved from demand-driven expansion to target-oriented strategic alignment under national decarbonization objectives. Third, the analysis integrates techno-economic considerations, institutional roles, and sustainability implications within a unified framework, allowing a holistic evaluation of policy effectiveness. By combining quantitative infrastructure indicators, strategic policy interpretation, and sustainability-oriented evaluation, this study advances the analytical depth of EV infrastructure research in the GCC context and provides a transferable framework for comparative regional assessment.

This paper addresses these issues by reviewing the state-of-the-art in EV charging technologies and examining case studies with a focus on the UAE. Section 2 provides background on EV and charger types. Section 3 discusses user charging behavior and its implications for infrastructure use. Section 4 outlines current challenges in charger deployment (sociological, physical, and technical factors). Section 5 and 6 evaluate emerging solutions, including smart charging and policy interventions. Section 7 presents an in-depth analysis of the UAE's EV charging infrastructure development from 2018 to 2025, highlighting deployment growth, technological shifts, and policy initiatives in the country's fast-evolving EV ecosystem. Finally, Section 8 offers conclusions and strategic recommendations for aligning the UAE's charging network expansion with its sustainable transportation goals.

2. Types of Electric Vehicles and Charging Infrastructure Configuration

2.1. Types of Electric Vehicles

As shown in Table 1, EVs can be categorized based on the type of propulsion and the battery used [13].

- HEV (Hybrid Electric Vehicle): A general term for vehicles that use two types of energy sources, typically combining a traditional engine with a battery-powered electric motor. HEVs are divided into different levels depending on technological sophistication and the contribution of the battery.
- PHEV (Plug-in Hybrid Electric Vehicle): Unlike HEVs, PHEVs can be charged externally. The battery plays a primary role in starting and driving, with the engine assisting only when the battery is depleted.

- EV (Electric Vehicle): This type eliminates the engine entirely and enhances battery capacity beyond that of PHEVs, relying solely on electricity for propulsion.
- FCEV (Fuel Cell Electric Vehicle): Instead of using an externally charged battery, FCEVs are powered by a fuel cell that generates electricity internally.

The battery is a core component of EVs, and must support high energy density and more than 500 full charge-discharge cycles to enable extended driving ranges. Common battery types include Nickel-Metal Hydride (Ni-MH) and lithium-polymer cells, both known for their high energy density and efficient charge/discharge performance.

A key control unit in EVs is the BMS (Battery Management System). The BMS manages essential functions such as driving range prediction, full charge control, overcharge prevention, and equalized charging between cells. It also monitors for battery cell or module failure and alerts users for battery replacement based on predicted battery life [14].

Table 1. Types of electric vehicles.

Category	HEV	PHEV	EV	FCEV
Power Source	Engine + Motor	Engine + Motor	Electric Motor	Electric Motor
Battery Type	Nickel-Metal Hydride	Lithium-Polymer Type	Lithium-Polymer Type	Fuel Cell
Driving Range	Over 100 km	Over 100 km	Up to 130 km	Up to 500 km
Maximum Speed	Over 150 km/h	Over 100 km/h	Over 130 km/h	Over 160 km/h

2.2. Configuration of Electric Vehicle Charging Infrastructure

To operate electric vehicles efficiently, the infrastructure must include a power supply network, a charging/discharging system, a billing system, a power grid operation system, and battery exchange stations, as illustrated in Figure 2. The EV infrastructure is designed to enable cost-effective and convenient charging in locations such as apartment complexes or public facility parking lots. The electricity charges incurred will be billed together with household utility fees, such as monthly maintenance charges. In addition to basic charging functions, the system will support real-time billing, remote monitoring, and charging status updates through RFID cards or home network systems, allowing users to easily access this information.

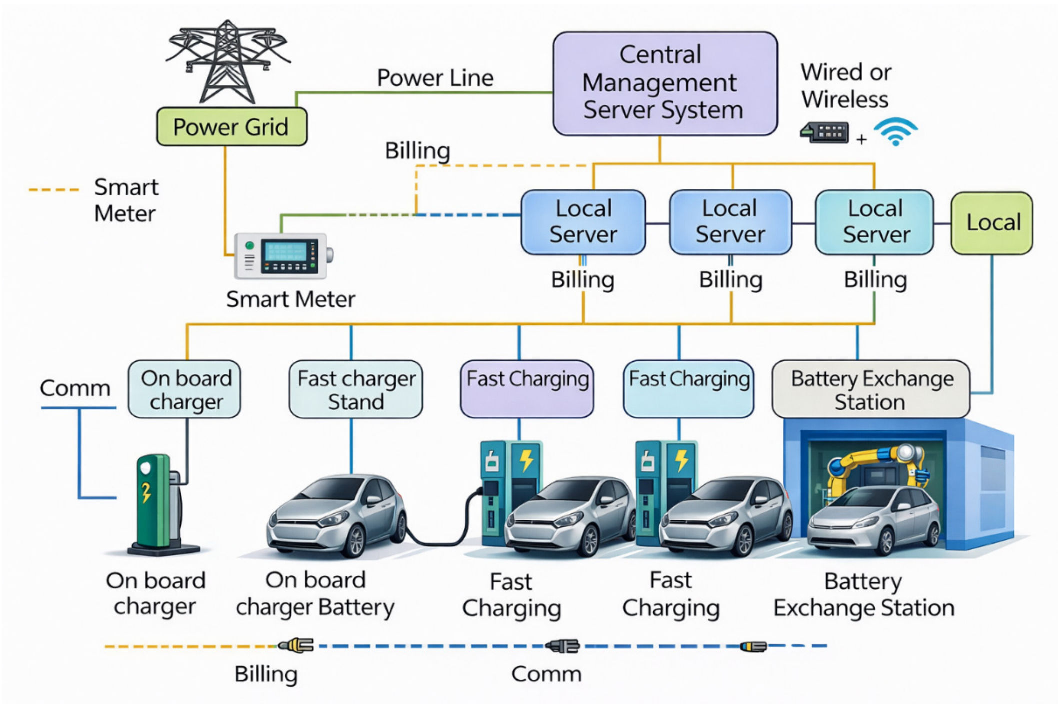

Figure 2. Electric vehicle charging system configuration.

Electric vehicle (EV) chargers are generally categorized into home chargers and public chargers, with two main types: slow chargers and fast chargers. Fast chargers can typically charge a vehicle in about 30 min. Fast chargers convert the grid AC power into DC, or convert DC power from renewable energy sources using a DC/DC converter to charge the vehicle's onboard battery. Figure 3 presents the structural configuration of a fast charger, where power conversion is performed externally to enable high-capacity, rapid charging.

As shown in Figure 3, the power conversion stages, including the AC–DC rectifier and the DC–DC converter, are implemented in the external charging station rather than inside the electric vehicle. Because the rectifier and DC/DC converter are located in the external charging system, fast charging is possible, enabling high-power energy transfer and significantly reducing battery charging time. On the other hand, slow chargers (also known as onboard chargers) have the rectifier and DC/DC converter integrated into the vehicle. This setup requires the vehicle to handle the power conversion process, which is typically limited to low capacity due to structural constraints, resulting in slower charging speeds [15,16]. Figure 4 illustrates the configuration of a slow charging system, in which power conversion components are integrated into the vehicle, resulting in lower charging capacity and longer charging time. Table 2 presents the main categories of electric vehicle chargers, including fast chargers, standard chargers, and home chargers.

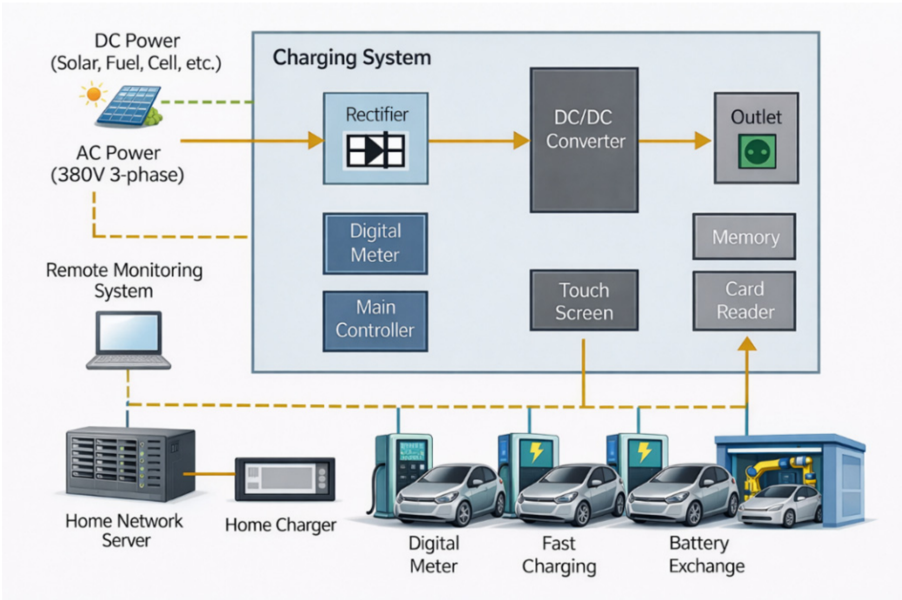

Figure 3. Structure of fast charger.

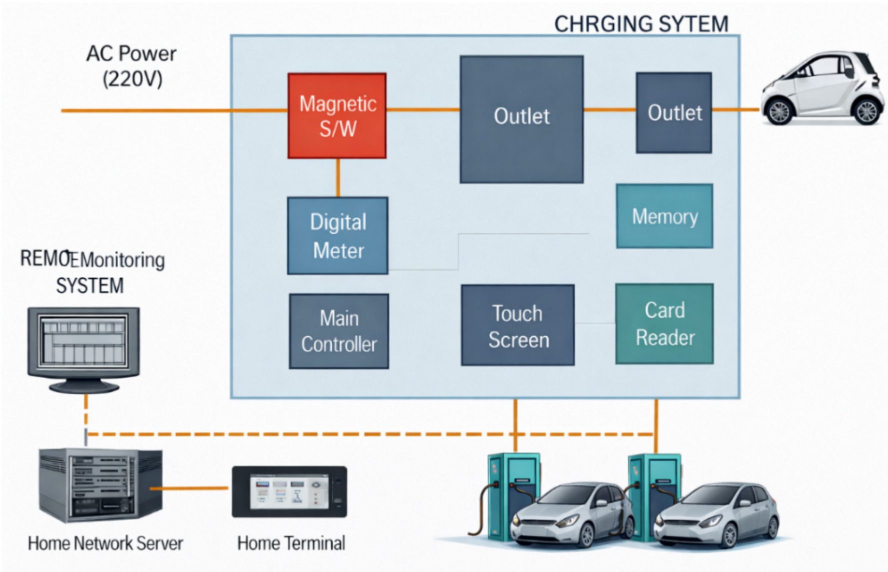

Figure 4. Structure of slow charger.

Table 2. Types of electric vehicle chargers.

Category	Fast Charger	Standard Charger	Home Charger
Image	[Fast Charger]	[Standard Charger]	[Home Charger]
Power Conversion Device	Installed in external charger	Installed in vehicle	Installed in vehicle
Operating Voltage/Current	50–450 V DC/100–150 A	220 V AC/15–45 A	220 V AC/15–45 A
Charging Time	15–30 min	6–8 h	6–8 h

2.3. Market Context and Classification of EV Powertrains

Global passenger-car markets have rapidly electrified: battery-electric vehicles (BEVs) now dominate new EV sales (around 11% of global light-vehicle sales in 2023) and represent roughly 70% of the world's EV fleet. Plug-in hybrids (PHEVs) contribute ~5% of new sales, while non-plug-in hybrids (HEVs) also retain a significant share in many markets. Fuel-cell EVs (FCEVs) remain niche (sales < 0.1% of global market). In the UAE, uptake is rising from a low base: EVs (BEVs + PHEVs) accounted for about 13% of new car sales in 2023 (up from ~3% in 2022). Combined EV + hybrid stock in the UAE reached ~147,000 vehicles by 2023. These trends reflect aggressive policy support: the UAE's Net Zero 2050 strategy and National EV Policy target 50% EVs on the road by 2050 (10% by 2030), with incentives (free registration/parking, reduced fees) and fast charging expansion (national network of ~914 public chargers by end-2023; Dubai alone > 1100 chargers by 2025).

Since 2020, all powertrains have advanced. BEV battery packs have seen higher energy density and halved in cost (≈$130/kWh in 2023), enabling longer range; ultra-fast DC chargers (200–350 kW) and 800 V architectures now allow 10–80% charging in ∼15–30 min. HEV/PHEV drivetrains have gained efficiency through improved hybrid systems, lighter motors and larger battery buffers. Fuel cells have improved in catalyst loading and durability, but remain costly and limited to a few models. Interest in e-fuels (renewable synthetic hydrocarbons) has grown as a carbon-neutral liquid fuel for existing ICE engines, though production is still early. Our classification retains four categories (HEV, PHEV, BEV, FCEV) to reflect these market realities. We follow IEA usage where "EV" often denotes BEV + PHEV. To avoid ambiguity, here "EV" refers to BEVs only, distinct from PHEVs and HEVs. This separation highlights BEV/PHEV growth while acknowledging hybrid and hydrogen options. We note this scheme does not cover, for example, mild-hybrid or internal-combustion vehicles running on e-fuels. Overall, the current market share and technology context validate our choice of categories and point to infrastructure and policy needs discussed next.

2.4. Residential vs. Commercial Charging

Electric vehicle charging infrastructure can be broadly categorized into residential and commercial charging, each differing in technical configuration, user behavior, infrastructure requirements, and grid impact. Residential charging typically occurs at private homes using Level 1 or Level 2 AC chargers with power ratings ranging from 3 kW to 11 kW. Charging sessions are characterized by long dwell times, often overnight, allowing gradual energy replenishment with relatively low stress on the distribution grid. Residential charging infrastructure is usually privately owned, requires minimal permitting complexity, and involves lower installation and operational costs.

In contrast, commercial charging encompasses public charging stations, workplace charging, retail charging hubs, and highway fast-charging corridors. These systems frequently include high-power AC chargers and DC fast chargers ranging from 22 kW to 350 kW. Commercial charging is associated with shorter dwell times, higher demand peaks, greater load variability, and more complex grid integration requirements. Unlike residential charging, commercial infrastructure often requires dedicated transformers, grid reinforcement, demand management strategies, and coordinated planning with utilities. Furthermore, commercial charging operates within a business model framework involving tariff design, utilization rate optimization, cost recovery, and public–private partnerships.

From a policy and infrastructure planning perspective, residential charging supports distributed load absorption and off-peak demand balancing, while commercial charging ensures accessibility for users without private parking and enables long-distance mobility. The balance between these two charging modes significantly influences grid stability, infrastructure investment strategy, and overall EV ecosystem sustainability.

3. Overview of Eco-Friendly Vehicle Technologies

3.1. Types of Eco-Friendly Vehicles

Since the early 2000s, growing concerns about fossil fuel depletion and environmental pollution caused by internal combustion engine (ICE) vehicles have led to increasingly stringent regulations on exhaust emissions. In response, attention has shifted toward eco-friendly vehicles that do not emit harmful gases, spurring innovation in alternative propulsion systems. Eco-friendly vehicles generally fall into several categories, including hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), fuel-cell electric vehicles (FCEVs), and battery electric vehicles (EVs). HEVs combine an internal combustion engine with an electric motor, drawing power from both sources. This type of vehicle is one of the most commonly adopted transitional solutions toward full electrification [17].

PHEVs, like HEVs, also utilize both an engine and a motor, but they differ in that their batteries can be recharged directly by plugging into an external power supply. This enables greater electric-only driving range and reduces reliance on the combustion engine. FCEVs operate based on a fuel-cell system that generates electricity through an electrochemical reaction between hydrogen stored in a tank and oxygen from the atmosphere. The resulting electricity powers the motor and produces only water vapor as a byproduct, making FCEVs a zero-emission solution. Finally, EVs rely entirely on electricity stored in batteries to drive the electric motor. These vehicles do not emit carbon dioxide (CO_2), nitrogen oxides (NO_x), or fine particulate matter, distinguishing them as a central component of next-generation mobility and a key strategy in addressing urban air pollution and climate change [18].

3.2. The Necessity of Electric Vehicles as Eco-Friendly Alternatives

The increasing urgency to address climate change and reduce environmental pollution has amplified the importance of promoting eco-friendly vehicles in the UAE. According to data from the UAE Ministry of Energy and Infrastructure and the Dubai Electricity and Water Authority, the number of registered eco-friendly vehicles—including electric, hybrid, and hydrogen vehicles—has shown a steady increase in recent years. Between 2017 and 2022, the number of electric vehicles alone grew from 25,593 to over 232,000 units, reflecting a strong national push toward sustainable mobility. This upward trend highlights the UAE's growing commitment to reducing carbon emissions and transitioning to low-emission transportation solutions as part of its broader green mobility and climate action strategies [19].

The steady rise in the registration of eco-friendly vehicles in the UAE—from 25,593 in 2017 to nearly 233,000 by 2022—further underscores the nation's transition toward sustainable transportation. Various factors influence consumer decisions when purchasing vehicles, including cost, performance, fuel efficiency, and ease of maintenance. However, electric vehicles have gained significant momentum in the UAE, largely due to global and local efforts to regulate internal combustion engine emissions and implement long-term bans on fossil-fueled vehicles. In addition, government-led initiatives such as the UAE Green Mobility Strategy, coupled with financial incentives like reduced registration fees, toll exemptions, and subsidized charging, have lowered the economic barriers to EV ownership. The growing environmental awareness among citizens, along with these proactive policies, reinforces the strategic role of electric vehicles as a key element in the UAE's broader efforts to achieve carbon neutrality and advance climate resilience in the transportation sector. The main categories of eco-friendly vehicles—including HEVs, PHEVs, EVs, and FCEVs are illustrated in Figure 5.

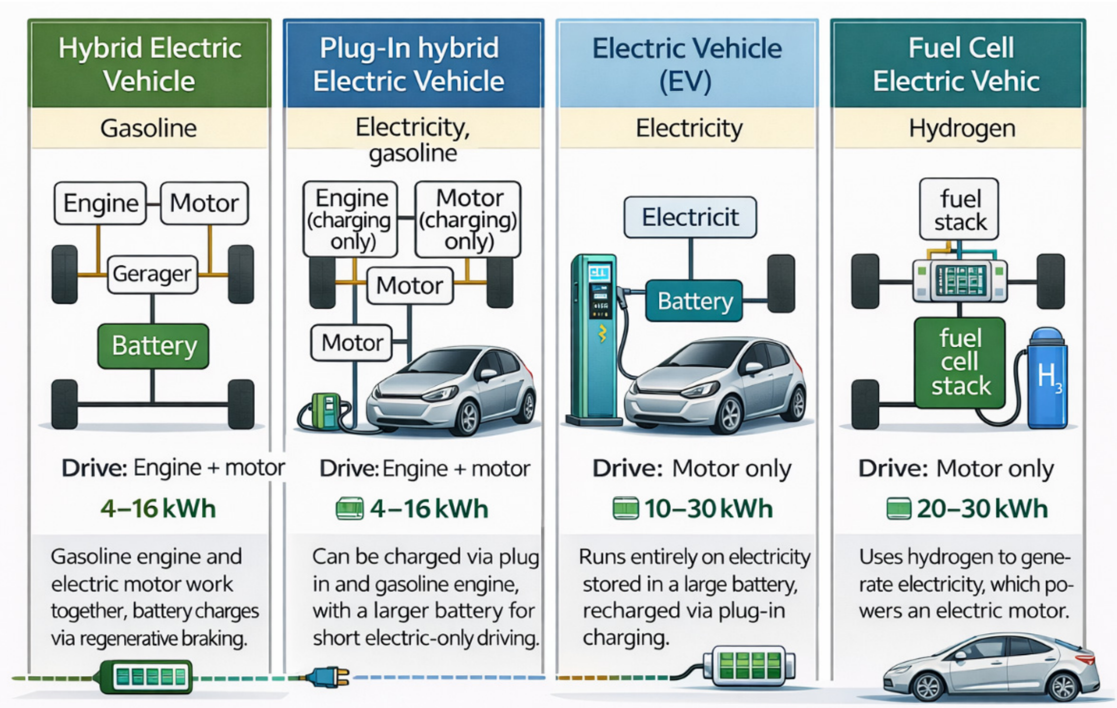

Figure 5. Types of eco-friendly vehicles.

3.3. Electric Vehicle Infrastructure

According to recent analyses from the UAE's Ministry of Energy and Infrastructure and data provided by the Dubai Electricity and Water Authority (DEWA), the number of electric vehicle (EV) chargers per 100 registered

EVs—a key indicator of EV infrastructure development—showed steady improvement up to 2017 but has since struggled to match the rapidly growing number of EVs on UAE roads. While government initiatives such as the UAE Green Mobility Strategy and Dubai's Smart Mobility Plan have accelerated EV adoption, the growth of the charging infrastructure has not kept pace. Table 3 outlines the estimated annual distribution of EVs and chargers within the UAE from 2015 to 2019 [20].

Table 3. Analysis of charger supply in the UAE.

Year	Chargers (Approx.)	Registered EVs (Approx.)	Chargers per 100 EVs
2015	300	1200	25.0
2016	650	2800	23.2
2017	1500	5500	27.3
2018	2750	11,000	25.0
2019	4000	22,500	17.8
2020	4500	35,000	12.9
2021	6000	60,000	10.0
2022	900	101,049	8.9
2023	914	147,000	6.2
2024	1400	190,000	7.4
2025	2000	250,000 (est.)	8.0

The declining trend in chargers per 100 EVs observed after 2017 does not necessarily indicate stagnation in infrastructure expansion. Rather, it primarily reflects the accelerated growth rate of EV adoption during this period. Although the total number of chargers increased substantially—from 1500 in 2017 to 4000 in 2019—the number of registered EVs expanded at an even faster pace. This dynamic suggests that EV uptake began outpacing infrastructure deployment, creating a temporary imbalance in the charger-to-vehicle ratio. From a planning perspective, this trend highlights the need for forward-looking infrastructure forecasting models that anticipate EV adoption growth rather than reacting to it. If infrastructure deployment consistently lags behind vehicle growth, range anxiety and congestion at charging stations may emerge as barriers to continued EV adoption. Therefore, maintaining a stable or improving charger-to-EV ratio is essential to ensure sustainable market expansion and user confidence. Similar patterns have been observed globally, where early EV adoption phases often exhibit temporary declines in charger-per-vehicle ratios due to rapid market acceleration before infrastructure fully scales.

The updated data for 2020–2025 reveal a distinct post-pandemic acceleration in EV adoption across the UAE. While charger deployment continued to grow steadily, EV registrations increased at a significantly faster rate between 2020 and 2023, resulting in a temporary decline in the charger-to-EV ratio. This pattern reflects rapid market expansion rather than infrastructure stagnation. However, beginning in 2024, the ratio shows signs of stabilization as national and emirate-level initiatives (e.g., DEWA Green Charger expansion, ADNOC fast charger rollout, and federal EV policy targets) accelerate infrastructure deployment. The emerging trend suggests a transition from reactive infrastructure expansion toward more strategic, forward-planned deployment aligned with national EV penetration targets. Maintaining this balance will be critical to prevent congestion at charging stations and sustain user confidence in the EV ecosystem.

A critical challenge alongside increasing the number of chargers is ensuring their strategic deployment to match user demand. For example, while Dubai and Abu Dhabi have the largest number of chargers, several high-density residential and commercial zones still lack sufficient fast-charging stations. According to DEWA's 2019 infrastructure report, although Dubai operated more than 240 charging stations under its EV Green Charger initiative, user demand far exceeded supply in areas with high commercial activity and apartment dwellers without dedicated parking [21,22].

Moreover, regions with growing interest in sustainability, such as Sharjah and Ras Al Khaimah, still face infrastructure bottlenecks. Even though the UAE has one of the fastest EV adoption growth rates in the GCC, the ratio of fast chargers to vehicles remains below optimal levels in many locations. Efficient planning requires accurate forecasting of regional EV growth and proactive deployment of fast chargers in both public and private sectors to ensure access and encourage continued EV adoption [23,24].

4. Electric Vehicle Industry Trends and Challenges

4.1. Industry Trends

The UAE government has launched several initiatives to support EV adoption and infrastructure development. For instance, the Ministry of Energy and Infrastructure and Dubai Electricity and Water Authority

(DEWA) have been at the forefront of deploying EV pilot zones and public charging stations across major cities such as Dubai, Abu Dhabi, and Sharjah. The charging infrastructure includes fast, semi-fast, slow chargers, and solar-powered stations.

Private sector companies are also playing a key role in advancing EV infrastructure. For example, Aldar Properties and Emaar have integrated EV chargers into their residential and commercial developments to accommodate the anticipated rise in EV usage. Tenants can use dedicated smart cards or mobile apps to access and pay for charging services. Meanwhile, Etisalat and du have explored innovative approaches, such as transforming underutilized telecom infrastructure (e.g., old telephone booths or mobile towers) into compact EV charging stations. These sites already have power and connectivity, making them ideal for repurposing with minimal retrofitting. The deployment model of DEWA's public charging system in Dubai is presented in Figure 6.

An example of adaptive infrastructure reuse, where a public telephone booth is converted into an EV charging station, is illustrated in Figure 7.

Figure 6. DEWA construction's charging system.

Figure 7. Charging station using a public telephone booth.

Bee'ah has also introduced cost-effective portable EV chargers installed in public parking lots and residential complexes. These chargers operate using smart cables equipped with metering and communication functions, enabling direct billing to users without the need for large-scale charging stations. This low-cost solution—up to 1/7th the cost of traditional chargers—is particularly suitable for high-density residential areas where allocating dedicated EV parking is difficult.

4.2. Current Issues in Charging Infrastructure Deployment

Despite the momentum in EV policy and urban mobility reform, several challenges must be addressed to accelerate EV adoption in the UAE. The limited energy storage capacity of EV batteries remains a concern, particularly compared to internal combustion engine vehicles. A standard 24 kWh battery allows for approximately 130 km of driving after 6–8 h of slow charging, which may be insufficient for long commutes in desert conditions. Moreover, as battery capacity increases, so does the weight and cost of the vehicle, posing a barrier to mass-market penetration. To overcome this, continuous technological innovation in battery design and materials is essential.

On the infrastructure side, expansion is hindered by low private sector participation. In many public buildings, the lack of short-term commercial viability discourages private investment in EV chargers. Consequently, deployment is still largely dependent on government programs, such as DEWA's Green Charger initiative and Abu Dhabi's Sustainable Transport Strategy. For residential buildings, especially apartment complexes, charger installation is often tied to marketing campaigns by developers to promote new construction projects, rather than comprehensive retrofitting of existing housing stock. Without strategic incentives or regulation, widespread deployment in existing multi-unit buildings remains limited.

5. Critical Review of Issues in Electric Vehicle Charging Infrastructure

5.1. Sociological Factors Related to Charging Infrastructure Issues

Among the sociological factors affecting EV charging infrastructure issues are the polarization in the distribution of charging infrastructure and the significant regional disparities in electric vehicle adoption rates. These have become major problems. According to global climate policy experts, countries around the world are continuously working to reduce carbon emissions under international agreements such as the Paris Accord. One of the most effective measures in this effort is to reduce greenhouse gas emissions from vehicles by promoting the adoption of eco-friendly vehicles such as electric vehicles (EVs). In line with this, the UAE government has also been actively working to expand EV deployment and support green mobility policies. Table 4 below presents the yearly trend in electric vehicle registrations, reflecting the UAE's growing interest in sustainable transportation. When analyzing EV registration trends by emirate, it is observed that regions like Dubai, Abu Dhabi, and Sharjah show significantly higher adoption rates compared to other emirates. This reflects not only a greater population and vehicle density in these emirates, but also the government's investment in charging infrastructure and green transport incentives [25].

Table 4. Growth of registered electric vehicles (EVs) in the United Arab Emirates (2017–2022).

Year	2017	2018	2019	2020	2021	2022
Number of EVs in UAE	25,593	55,758	101,049	134,962	231,497	232,970

5.2. Physical Factors behind Charging Infrastructure Issues

The physical issues associated with electric vehicle (EV) charging infrastructure primarily stem from the current system, in which consumers are required to visit fixed charging stations (FCS) to recharge their vehicles. This approach creates significant limitations, especially as the number of EVs continues to rise and the availability of charging infrastructure struggles to keep pace. This fixed model presents several challenges that hinder efficient EV adoption. First, there are accessibility concerns: EV users often face difficulties in reaching charging stations, particularly when traffic congestion increases travel time, raising the risk of battery depletion before arrival. Second, prolonged waiting times at charging stations are another critical issue. Many users report experiencing delays of at least an hour, during which their batteries may fully discharge. This leads to "range anxiety"—the fear of not finding an available charger in time—which discourages EV usage and impedes broader market expansion. Moreover, fast chargers, while desirable, involve high installation costs and suffer from low utilization rates, making it difficult to recover investments. Consequently, a vicious cycle of limited supply and low demand persists. Third, spatial constraints also pose significant problems. In regions with a low density of EV chargers, the long duration required to complete a charge often results in vehicle lineups, exacerbating both traffic congestion and parking shortages. In residential complexes such as apartments, limited parking further complicates the issue; EVs may occupy charging spots without actively charging, especially since many vehicles do not clearly indicate charging status. Lastly, the maintenance and operational burden grows as the number of chargers increases, leading to frequent malfunctions and service disruptions. These compounded physical limitations collectively represent major barriers to the scalable and sustainable development of EV infrastructure [26].

5.3. Issues Arising from EV-Specific Characteristics

5.3.1. Rapid Battery Depletion due to Onboard Systems

For electric vehicles equipped with autonomous driving technologies, battery consumption tends to increase while the self-driving functions are active. This is because autonomous driving requires continuous data collection and processing via onboard sensors, cameras, and radar systems, all of which consume electricity when in use. These autonomous systems must continuously monitor and analyze their surroundings in real time, which demands significant computational resources and, as a result, consumes additional energy. This heightened energy consumption tends to reduce battery efficiency considerably. Survey findings reveal that many users notice a sharp drop in battery performance after activating autonomous features, leading to increased anxiety about remaining battery levels. Most users report beginning to feel the need to recharge once their battery level drops below 30%, with many indicating that a remaining charge of 20–30% is the point at which they actively seek a charging opportunity. Some even consider 10–20% to be a critical threshold for recharging. This suggests that the lower the remaining battery percentage, the higher the driver's charging anxiety becomes—an important consideration for UAE policymakers and planners working on smart mobility and public charging availability [27].

5.3.2. Relationship between Fast Charging, Slow Charging, and Battery Lifespan

Fast charging tends to cause more thermal stress than regular (slow) charging. This thermal effect refers to a phenomenon where high heat is generated in a short amount of time due to electrical activity, which can lead to overheating and related issues. While high-speed charging offers the benefit of significantly reducing EV charging time, repeated use can lead to thermal stress on the battery, ultimately shortening its lifespan and gradually increasing the time required for charging [28]. As shown in Table 5, the main characteristics of the system components are presented.

Table 5. Fast chargers and slow chargers.

Type	Fast Charging Station	Fast Charging Station	Regular Charging Station	Regular Charging Station
Supply capacity	50 kW	100 kW	7 kW	3.3 kW (Portable, allowable standards, 15 A)
Charging time	From complete discharge to about 80% takes approximately 60 min	From complete discharge to about 80% takes approximately 30 min	From complete discharge to about 80% takes approximately 7 h	From complete discharge to full charge takes approximately 16 h

6. Electric Vehicles and Charging Infrastructure

6.1. Relationship between EVs and Charging Infrastructure

Electric vehicles (EVs) generally refer to vehicles that store electric energy in a battery and move using power supplied from the battery. Depending on how the electricity is supplied, EVs are classified differently. Vehicles that use only battery electricity to drive an electric motor are known as Battery Electric Vehicles (BEVs). Vehicles that use an internal combustion engine as an auxiliary power source are known as Plug-in Hybrid Electric Vehicles (PHEVs). PHEVs can be charged externally, and the battery power is used to operate the electric motor, while the engine supports propulsion when necessary. BEVs and PHEVs together are often referred to as Plug-in Electric Vehicles (PEVs), since they are plugged into a power source to recharge their onboard batteries. Among PEVs, there are several subtypes depending on their All-Electric Range (AER), which indicates the maximum distance that can be traveled on battery power alone [29]. As shown in Table 6, the main characteristics of the system are summarized. According to NRC (2015), PEVs can be categorized into the following four types based on AER [30]:

Table 6. Four types of plug-in electric vehicles (PEVs).

PEV Type	Description	Example (AER)
Long-Range BEV	Can drive more than 160 km on battery alone (shorter time per charge = longer AER)	Tesla Model S (AER = 426 km)
Limited-Range BEV	Equipped with a smaller battery than long-range BEVs (lower cost, shorter AER)	Nissan Leaf (AER = 138 km)
Range-Extended PHEV	Equipped with a small battery; uses engine after battery is depleted	Chevrolet Volt (AER = 61 km; total range = 612 km)
Minimal PHEV	Smallest battery among PHEVs; short battery range, mostly uses engine	Toyota Plug-in Prius (AER = 10–18 km; total range = 869 km)

The overall configuration of the EV charging equipment system, including the power supply, charger, interface, and information management components, is illustrated in Figure 8.

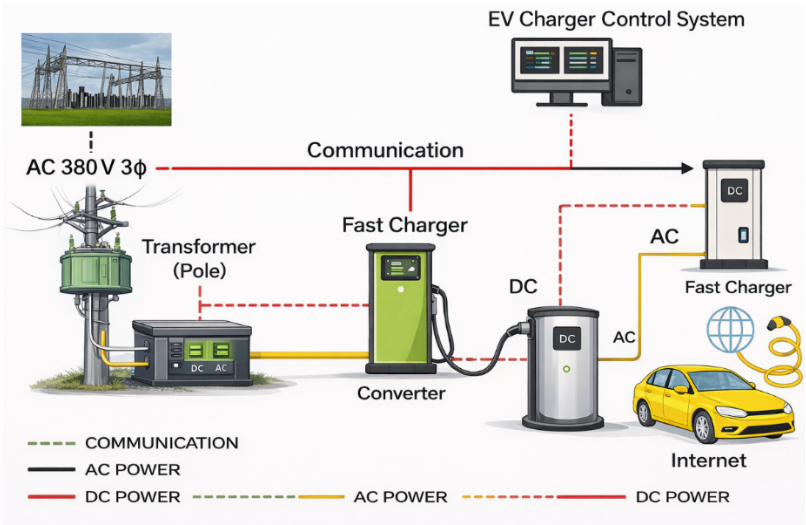

Figure 8. Configuration of electric vehicle charging infrastructure.

Electric vehicle (EV) charging infrastructure broadly encompasses four main components: the power supply system, the charger, the interface, and the charging information system. The power supply system includes the electrical equipment necessary to deliver electricity to EVs—such as electric meters, service entrance wiring, distribution boards, and circuit breakers. The interface comprises components like couplers and cables that connect the charger to the vehicle, enabling power transfer [31].

The charging information system refers to a software-based platform that collects real-time data on the location and operational status of charging equipment. This system monitors the performance of chargers and provides users with real-time access to this information via web or smartphone platforms. While these components form the peripheral elements of EV charging infrastructure, the charger itself lies at the core. The power supply system connects the charger to the electric grid, and the interface bridges the charger with the vehicle—together enabling seamless power delivery [32]. Figure 9 presents the structural framework of the electric vehicle charging equipment configuration system and its main operational components.

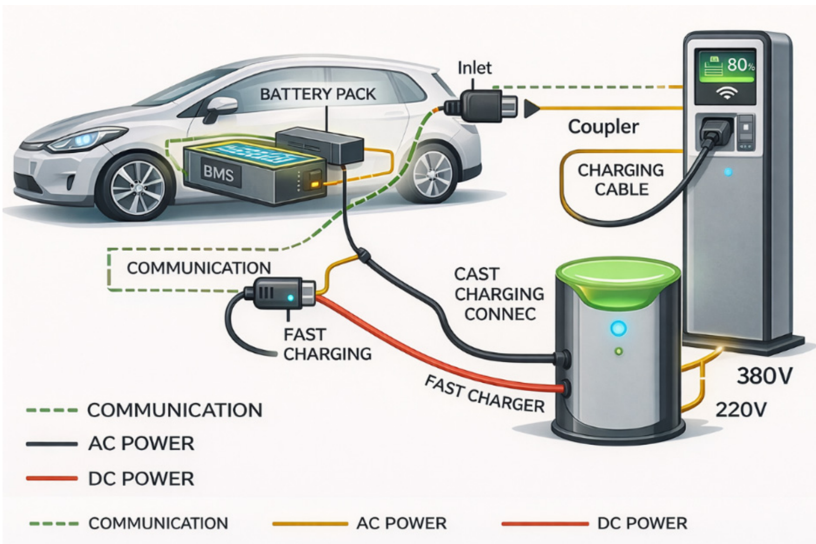

Figure 9. Electric vehicle charging equipment configuration system.

According to NEC (2008), an Electric Vehicle Supply Equipment (EVSE) is defined as "a specially installed device for transmitting electricity from wiring devices such as grounding wires, neutral wires, equipment grounding conductors, EV connectors, inlets, plugs, and all other fixed devices or outlets to electric vehicles" [33].

EVSE regulations encompass all components presented earlier, including charging infrastructure and interface equipment, and can be understood as a concept that includes both chargers and interfaces. These systems perform the role of maintaining stability between the vehicle and the charger through mutual communication during or before charging and monitoring any variable conditions that may affect the charging process [34].

6.2. Types of Electric Vehicle Charging Methods

Classification by Type of Charger

As previously mentioned, EV charging systems consist of chargers and interface components. These chargers are broadly classified into:

- Conductive charging chargers (direct connection)
- Non-conductive (or wireless charging) chargers

(1) Conductive Charging

This method involves directly connecting the PEV's charging port and charger to supply power. The battery installed in the vehicle is charged to a certain level, and depending on the charging time required, the chargers are classified into slow chargers and fast chargers [35] (Table 7).

Table 7. Comparison of fast and slow charging methods.

Category	Input Voltage	Output Voltage	Supply Capacity	Charging Time
Fast Charging	AC 3-phase 4-wire 380 V	DC 380–450 V/380 V direct	50 kW	15–30 min
Slow Charging	AC single-phase 220 V	AC 220 V single	6–7.7 kW	5–6 h

Slow chargers are typically used to supply 220 V AC power to the PEV through a connected cable. This power is then converted to DC using an onboard charger (usually 3–7 kW), which is used to charge the vehicle's battery. Most commonly, slow chargers with a power capacity of 6–7.7 kW are used domestically, and depending on the battery capacity, the charging time generally takes about 8 to 10. On the other hand, fast chargers transmit and receive control signals and supply DC power at variable voltages ranging from 100 to 450 V, or AC power at 380 V, to charge EV batteries. This method enables high-voltage, high-capacity charging, significantly reducing charging time to about 15–30 min depending on battery capacity. 50 kW-class fast chargers are commonly used due to the need to deliver high-capacity power [36].

Fast chargers currently employ a combination of connector standards, including the DC Combo, CHAdeMO (CHArge de MOve), and AC 3-phase systems.

- The DC Combo system allows the simultaneous use of an AC module for slow charging and a DC module for fast charging. This system is adopted by recent models such as the Chevrolet Spark EV and BMW i3.
- The CHAdeMO system, developed in 2008 by Tokyo Electric Power Company along with Nissan, Mitsubishi, Fuji Heavy Industries, and Toyota, is now used by manufacturers like Nissan, Mitsubishi, Citroën, and Peugeot. It is a DC-based fast-charging system; therefore, using AC power requires a separate connector and inlet.
- The AC 3-phase system, adopted by Renault in France, does not require a separate DC conversion adapter and offers faster charging compared to traditional DC-based systems.

(2) Non-Contact Charger (Wireless Charger)

Unlike conductive chargers that require direct physical connection to the PEV, wireless chargers operate without physical contact. These non-contact or wireless charging systems use underground power lines embedded with magnetic core materials beneath parking surfaces to generate alternating current. A receiver unit installed on the underside of the vehicle captures the magnetic field induced from the ground and converts it into current via electromagnetic induction. The generated current is then rectified and used to charge the vehicle battery.

Charging services using wireless (non-contact) chargers are drawing increasing attention due to advantages such as user convenience, reduced installation space, and elimination of cable management. However, most systems are still in the pre-commercial stage, and it is expected that full-scale commercialization will begin in at least one to two years [37].

6.3. Types of EV Charging Methods: Classification by Charging Location

Another way to classify EV charging methods is by installation location, which typically falls into two categories:

- Residential Charging (Home Charging): Chargers installed within the private residence (especially single-family homes) of the PEV owner, used exclusively for household use.

- Commercial Charging: Chargers installed outside the PEV owner's home, accessible in public or commercial locations [37].

6.3.1. Residential Charging

Residential charging is widely regarded as the most efficient method for electric vehicle (EV) charging, as vehicles typically remain parked at home for extended periods throughout the day. This makes home-based charging highly convenient and practical for most users. In the UAE, where many residents have access to private or semi-private parking spaces within villas or residential compounds, the adoption of residential charging is expected to account for a significant portion of overall charging demand. However, challenges may arise in expanding this method due to the UAE's diverse housing landscape, particularly in densely populated urban areas where a large proportion of the population resides in apartment buildings and high-rise communities. In such multi-unit residential environments, parking spaces are commonly shared, making it difficult for individual EV owners to consistently access a dedicated charging point [38].

To address this issue, the use of portable chargers is gaining attention as a flexible alternative. One proposed solution involves installing 220 V outlets equipped with RFID (Radio Frequency Identification) readers in shared residential parking areas. EV users can carry portable chargers and connect them to their vehicles using these outlets. Once authenticated through the RFID system, the user's electricity consumption is recorded and relayed to the energy provider for accurate billing. Adopting such systems in residential complexes across the UAE could provide a scalable and user-friendly charging solution, particularly in settings where fixed chargers for each parking space are not feasible. This approach not only supports greater EV adoption but also aligns with national goals for sustainable mobility and smart city infrastructure [39].

In an effort to support the expansion of electric vehicle (EV) charging infrastructure, some countries have implemented regulations requiring new residential complexes with a certain number of parking spaces to include EV charging facilities. A similar approach could be considered in the UAE, especially for newly developed high-density apartment communities. However, a common limitation of such regulations is that they often apply only to new developments, excluding existing buildings from the requirement. Furthermore, without effective enforcement mechanisms, these mandates may lack the necessary force to ensure full compliance.

While these initiatives can contribute to shifting a portion of charging demand toward residential solutions, structural and technical limitations remain. Achieving the level of residential EV charging penetration seen in regions such as the United States or Europe may prove challenging in the UAE, particularly in high-rise urban environments. Moreover, as automakers increasingly release battery electric vehicles (BEVs) equipped with larger-capacity batteries for long-distance travel, the demand for faster and more accessible charging options is expected to grow. This trend points to a rising importance of commercial charging solutions, especially outside residential zones [40].

6.3.2. Commercial Charging

Commercial charging refers to charging infrastructure located outside of the EV owner's home. This includes installations at workplaces, allowing employees to charge their vehicles during working hours, as well as chargers installed on private properties for exclusive use—such as those available to residents of condominiums, hotel guests, or airport users. These systems are typically semi-private, meaning access is restricted to a specific user group. In contrast, public commercial charging systems are accessible to the general public, either free of charge or on a paid basis. These installations can be found in locations such as shopping malls, service stations, city parking lots, or roadside EV hubs, and are expected to play a crucial role in supporting widespread EV adoption in the UAE.

Among non-public charging options, workplace charging has gained significant attention, as workplaces are typically the location where vehicles are parked for the longest period during the day, aside from the home. For this reason, in regions such as the U.S. and Europe, workplace charging—along with residential charging—is recognized as a key method to meet the majority of EV charging demand. Consequently, workplace charging installations are often prioritized in charging infrastructure plans. In the UAE, the motivation for companies to install EV chargers in employee parking areas can be twofold: firstly, to support the adoption of EVs among employees, and secondly, to enhance the company's image as environmentally responsible. In the early stages of adoption, this infrastructure can also help promote the use of low-emission vehicles by making workplace charging a visible and accessible option.

Public commercial charging also plays a critical role in reducing range anxiety—drivers' concern about running out of battery power without access to charging points. As EVs become capable of longer travel ranges, particularly with the introduction of models equipped with larger batteries, the availability of conveniently located charging stations is key. Public charging points placed in commercial zones such as shopping centers, public car parks, or along highways can help address these concerns by ensuring drivers have access to energy wherever they go [41].

In densely populated or high-traffic regions of the UAE, commercial and public charging stations are expected to carry a larger share of the overall charging burden. This mirrors trends seen in North America and Western Europe, where a relatively high portion of commercial charging infrastructure is publicly accessible due to similar urban dynamics. Ultimately, to achieve this, it is necessary to install public charging stations that are accessible anytime, anywhere. However, as previously mentioned, these public charging stations are not intended solely for the convenience of PEV users. Given this, it is unrealistic to expect private investors—who prioritize profitability—to take the lead. Therefore, public charging infrastructure should be considered part of the public domain, with central and local governments or public sectors bearing a certain level of responsibility for their provision and funding.

7. EV Charging Infrastructure in the UAE (2022–2024)

Recent data indicates that the United Arab Emirates (UAE) has seen a rapid expansion of electric vehicle charging infrastructure from 2022 to 2024, in parallel with its growing EV adoption. Figure 10 illustrates the sharp upward trajectory in public charging points: from roughly 200 chargers in 2018 to over 900 by 2023, and doubling again to around 2000 by mid-2025. This growth reflects concerted efforts by both government and private stakeholders. Dubai dominates the network—by August 2025 the Emirate alone surpassed 1270 public charging points (more than half the national total) [42]. Abu Dhabi ranks second, while smaller emirates (e.g., Umm Al Quwain) still have only a handful of stations. Notably, the UAE's charger-to-EV ratio (approximately 25 electric cars per public charger) is now on par with that of leading EV markets, alleviating range anxiety and supporting further EV uptake. In a global context, however, the UAE's absolute number of chargers remains modest—for instance, Singapore already operates ~19,000 public chargers and targets 60,000 by 2030. This underscores that while the UAE leads in the Gulf region's infrastructure rollout, it is still catching up to more mature markets in charger density and coverage.

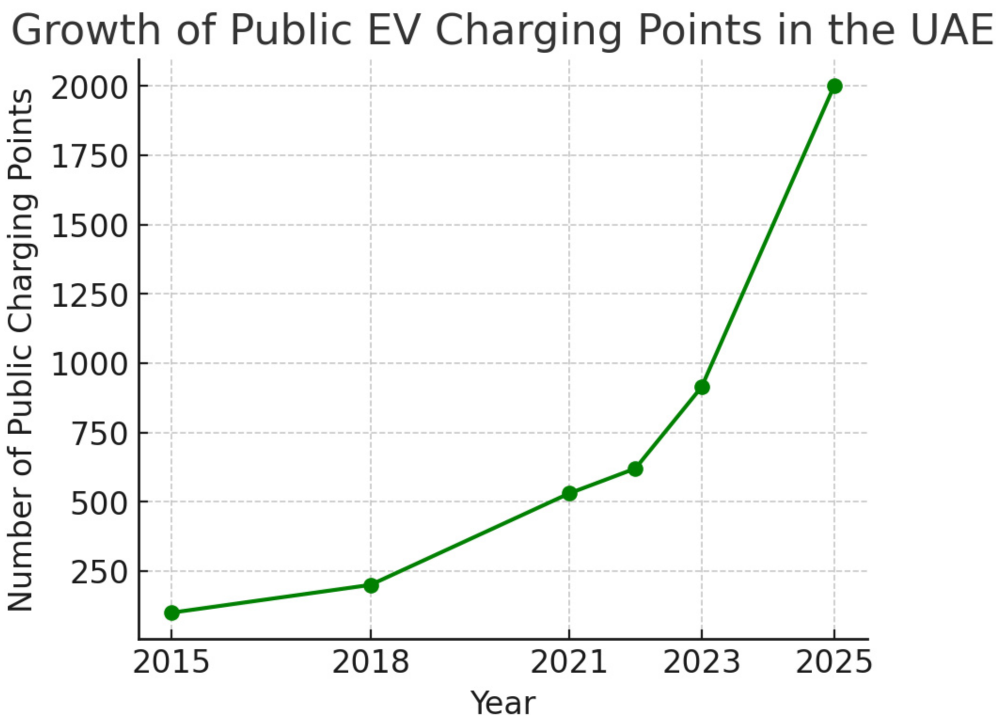

Figure 10. Growth of public EV charging points in the UAE.

Despite this progress, charger deployment is still racing to keep up with rising EV uptake—recent estimates suggest the UAE may need on the order of 20,000+ public charge points by 2030 to meet demand, far above the current trajectory [43]. This underscores the importance of sustained investment and strategic planning to bridge the gap between charging infrastructure availability and EV adoption rates.

7.1. Distinguishing Descriptive Reporting from Critical Analysis in the UAE Case Study

The UAE case study presented in this paper is structured to clearly differentiate between descriptive reporting and critical analysis in order to enhance analytical rigor and methodological transparency. Descriptive reporting in this context refers to the systematic presentation of factual information, including infrastructure deployment numbers, policy timelines, charger distribution statistics, government initiatives, and quantitative indicators such as chargers per 100 EVs. These descriptive elements establish the empirical foundation of the case study and are derived from official reports, regulatory documents, and publicly available datasets.

However, descriptive data alone does not explain whether infrastructure development has been adequate, efficient, or strategically aligned with long-term sustainability goals. Therefore, the present study extends beyond descriptive reporting by incorporating critical analysis that evaluates infrastructure performance relative to EV adoption growth, spatial distribution patterns, technological maturity, and policy effectiveness. For example, while the total number of chargers increased substantially between 2018 and 2025, the charger-to-vehicle ratio declined during certain years, indicating that infrastructure expansion lagged behind EV market acceleration. This observation moves beyond simple reporting and highlights a structural imbalance that may influence user experience, congestion risk, and range anxiety.

Furthermore, critical analysis is applied to assess whether infrastructure deployment has been proactive or reactive. The UAE's expansion strategy initially followed a demand-driven model, where charger installation responded to growing EV registrations. However, evidence from recent years suggests a transition toward anticipatory planning aligned with national EV penetration targets under the Net Zero 2050 strategy. This shift represents not merely quantitative growth but a strategic evolution in planning philosophy. Such interpretation reflects analytical reasoning rather than descriptive narration.

The case study also evaluates socio-technical dimensions, including regional disparities in charger distribution, private sector participation barriers, and economic sustainability of fast-charging investments. While descriptive reporting documents the number of chargers installed by entities such as DEWA and ADNOC, the analysis critically examines utilization rates, cost recovery challenges, and the dependence on government-led deployment. This distinction enables a more comprehensive understanding of structural constraints within the UAE EV ecosystem.

By explicitly separating factual presentation from evaluative interpretation, this subsection strengthens the academic contribution of the UAE case study. It ensures that the manuscript does not merely catalogue infrastructure developments but systematically assesses their implications for long-term sustainability, market stability, and policy effectiveness. This analytical framing enhances the scholarly depth of the study and addresses the need for clearer differentiation between descriptive and critical components.

7.2. Deployment Growth and Geographic Distribution

The charger deployment growth in the UAE has been exponential. In Dubai, the state utility (Dubai Electricity and Water Authority, DEWA) launched the EV Green Charger initiative in 2014, installing an initial 100 public chargers and expanding to 200 by 2018. By the end of 2022, DEWA's network reached 350 stations (620 charging points) across Dubai, and free charging incentives had helped boost EV usage. Nationwide, the total crossed 900 public chargers in 2023, nearly a 50% increase over 2022. This acceleration is strongly centered in urban hubs. As of 2023, Dubai and Abu Dhabi together host the majority of UAE chargers, reflecting their higher EV adoption and supportive local programs. Dubai's extensive network (over 370 "Green Charger" stations by 2023) is strategically distributed at malls, airports, parking lots and highways, ensuring that an EV driver is usually within reach of a station. Abu Dhabi, while initially slower to expand, had about 250 public chargers by late 2023 and has been quickly catching up through new installations at petrol stations and municipal parking areas. In contrast, the Northern Emirates (Sharjah, Ajman, Ras Al Khaimah, Fujairah, Umm Al Quwain) are still developing their infrastructure—for example, Umm Al Quwain had fewer than 10 public chargers as of 2025. Sharjah is a notable exception among them, having recently invested in dozens of new stations (including high-power chargers) through public-private partnerships, as discussed below. This geographic disparity highlights the need for continued expansion beyond the main cities to create a truly national charging network. Indeed, federal plans call for corridor fast-chargers on highways linking all emirates to facilitate inter-city EV travel. Overall, the deployment trend in 2022–2024 is one of broad-based growth with an urban concentration: the UAE has laid a robust foundation of chargers in its biggest cities and is now extending coverage to smaller markets and connecting roads.

7.3. Technological Trends: AC vs. DC Fast Charging

In tandem with growth in numbers, the UAE's charging infrastructure is evolving technologically—shifting from predominantly slower AC chargers toward more DC fast chargers. Early deployments were almost entirely AC charging stations (Level 2, up to ~22 kW) suitable for longer parking durations. These AC chargers still form the backbone of the network at locations like shopping malls, offices, and residential complexes. By end-2022, for example, the vast majority of the ~620 public charging points in Dubai were AC outlets. Typical units are the "Public" dual 22 kW AC posts and wallbox chargers, which can recharge an average EV in 4–8 h—adequate for destination or overnight charging. In contrast, DC fast charging capability was initially limited. As of 2022, DEWA had installed only two ultra-fast (150 kW) DC stations in Dubai, and perhaps a few dozen standard 50 kW DC chargers at highway petrol stations. This began to change rapidly in 2023–2024. The share of DC fast chargers in the UAE's mix has risen substantially, reflecting a push for higher power charging to enable quick turnarounds. For instance, ADNOC Distribution (the national fuel retailer) went from operating 53 fast chargers in 2023 to over 90 by mid-2024, with a goal of 150–200 fast chargers by the end of 2024. Many of these are high-power chargers (150–350 kW) being installed on major routes and gas stations, capable of delivering an 80% charge in ~20–30 min. Similarly, Sharjah introduced 100 ultra-fast chargers in 2025 as part of its new network rollout. Figure 11 illustrates this trend: in 2022, an estimated ~97% of public chargers were AC, but by 2024 DC fast units comprise roughly 15–20% of the public network (and an even greater share of charging output). This transition is aligned with global trends towards faster charging—although AC stations remain vital for workplaces and home locations, drivers increasingly expect rapid charging options on highways and at hubs to reduce downtime. The UAE government's strategy explicitly emphasizes "green fast and ultra-fast chargers," targeting 1000 fast charging stations in Dubai by 2025. In summary, the 2022–2024 period saw the charging infrastructure not only multiply in count but also diversify in technology: the network is moving beyond low-power convenience charging to incorporate a significant (and growing) proportion of DC fast chargers that support long-distance travel and high-volume use cases (taxi fleets, transit corridors).

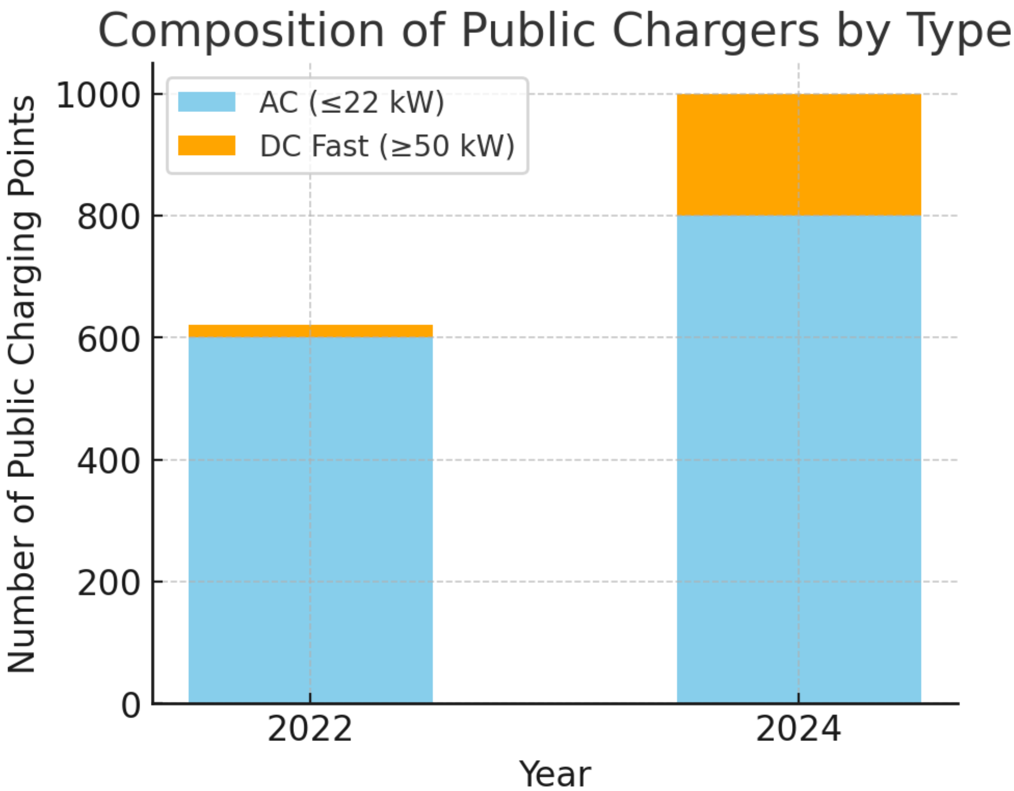

Figure 11. Composition of public EV chargers by type.

7.4. Government Initiatives and Private Sector Involvement

The impressive build-out of UAE's EV charging infrastructure has been driven by proactive government policies coupled with increasing private-sector involvement. On the government side, a clear strategic framework is in place. In 2023, the UAE Ministry of Energy and Infrastructure (MoEI) launched a National Electric Vehicles

Policy to unify charging standards, set tariffs, and encourage a nationwide charging network. A headline target is to install 10,000 public charging stations across the country by 2030 (up from 914 in 2023). In support of this, federal authorities formed a joint venture called UAEV (between MoEI and Etihad Water & Electricity) to roll out chargers in underserved areas; UAEV began installing 100 new stations in 2024 as a step toward 1000 stations by 2030 [44]. At the emirate level, Dubai's government has been especially active. DEWA's Green Charger initiative (launched 2014) provided free charging to registered EV owners until 2021 and grew the city's network to 370 stations by 2023. Dubai aims for 1000 Green Charger stations by 2025, effectively tripling its 2022 capacity. To achieve this, Dubai introduced a comprehensive regulatory framework in 2024 that, for the first time, licenses private operators to develop and operate charging stations. This has opened the door for private investment and innovation in a sector previously dominated by public utilities. Indeed, DEWA has already issued Charge Point Operator licenses to Tesla and to UAEV (the federal JV) as of 2024, enabling these entities to run chargers in Dubai's market.

Other public-sector players are also contributing. In Abu Dhabi, the state oil company ADNOC Distribution is leveraging its vast petrol station network to deploy chargers. Through a partnership with TAQA (Abu Dhabi's energy company) called E2GO, ADNOC plans an unprecedented 70,000 charging points in Abu Dhabi by 2030—an ambitious figure that includes home/business installations as well as public stations. Operationally, ADNOC had about 90 fast chargers in place by mid-2024 and is on track for 150+ by end-2024, focusing on 50–150 kW DC units at highway fuel stops. Meanwhile, Sharjah's city government and the environmental firm BEEAH announced a project in 2022 to install "hundreds of EV chargers" across Sharjah's public parking lots and residential areas. By 2025, Sharjah had rolled out its first 100 ultra-fast (150 kW) chargers under this program, significantly boosting charging availability in the northern emirates.

Crucially, the role of the private sector has shifted from peripheral to central in the past two years. The new federal EV policy explicitly allows private companies to build and operate stations (under regulated tariffs), spurring investments from various stakeholders. Automobile companies have been active: Tesla, for example, established a Tesla Supercharger network in the UAE, installing its first 26 stations by 2018 and expanding further by 2022–2023. These Tesla-run DC stations (120–250 kW) provide brand-specific fast charging and are now being partially opened to non-Tesla EVs as well. Retail and real estate developers are also investing in chargers as value-added services—many new malls, hotels, and residential projects now come with dedicated EV charging bays. A notable private initiative is DEWA's collaboration with Parkin (a parking management firm), which in 2025 began integrating EV chargers into major public parking facilities in Dubai. Additionally, several UAE-based startups and energy companies are entering the charging services space (e.g., installers, software providers for charger billing and monitoring). The government has encouraged this through public-private partnership (PPP) models: Dubai's Supreme Council of Energy formally endorsed PPP-based development of new charging stations in 2024. As a result, public agencies share costs and responsibilities with private operators, accelerating deployment. Early evidence of success is seen in the 72% jump in Dubai's charge points during H1 2025 once private CPOs were active. Overall, the 2022–2024 period marked a transition from a government-provisioned infrastructure to a hybrid model wherein private investment, innovation, and operational expertise are harnessed to scale up the network. This collaborative approach is aligned with international best practices and is expected to continue driving the UAE's charging infrastructure growth toward its 2030 goals.

7.5. Regional and Global Context

Placing the UAE's charging infrastructure progress in a broader context, it is evident that the country has become a regional leader. As of 2024, the UAE accounts for the largest share of public EV chargers in the Gulf Cooperation Council (GCC) region. Neighboring Gulf countries, while also ramping up efforts, lag behind in absolute numbers—for example, Qatar had only ~300 charging points by 2025 and Oman around 50 by 2024. Saudi Arabia, with a much larger area, is in earlier stages: it announced a target of 5000 fast chargers by 2030 (through the EVIQ initiative) but had only a few hundred installed as of 2023. Against this backdrop, the UAE's ~2000 public chargers and comprehensive policy framework stand out as a pioneering model in the Middle East. This leadership can be attributed to the UAE's broader sustainability agenda (e.g., Net Zero 2050) and its willingness to invest early in green infrastructure. However, when compared globally, the UAE still has room to grow. Leading EV markets like China and the EU deploy chargers an order of magnitude more densely—China adds hundreds of thousands of public chargers annually, and countries like the Netherlands have over 100,000 public chargers covering virtually all urban areas. The UAE's approach of combining AC destination charging with strategic DC fast charging mirrors strategies in Europe and North America, but the scale is smaller. One metric underscores this: electric cars as a percentage of new sales reached ~5% in the UAE in 2023, similar to global averages, yet the charger count per capita remains lower than in EV-intensive countries. The government's planned investments (e.g., 10,000 chargers by 2030) should significantly bridge this gap, providing roughly one charger per 20–25 EVs in line with international benchmarks. In sum, the UAE's 2022–2024 advances in EV charging infrastructure demonstrate a successful fast-follower strategy—leveraging lessons from global EV leaders to implement a tailored, ambitious deployment at home. Continued expansion at the current pace, coupled with technological upgrades (smart charging, vehicle-to-grid integration, etc.), will be critical for the UAE to support the mass adoption of EVs anticipated by 2030 and to fulfill its role as a regional exemplar of sustainable transportation infrastructure.

7.6. Technology Mix of Public Charging Infrastructure

Accompanying the increase in sheer numbers is a shift in the technology mix of UAE's charging network. Early deployments were predominantly AC "slow" chargers (Level 2 chargers up to ~22 kW) suitable for longer parking durations at malls, offices, and residences. As of 2022, an estimated ~97% of public chargers in the UAE were Level 2 AC units. These form the backbone of day-to-day charging needs, typically adding 20–30 km of range per hour of charge. DC fast chargers were initially scarce—for example, Dubai's utility (DEWA) had only two ultra-fast 150 kW stations installed by 2022 (along with a few dozen standard 50 kW DC units on highways). This situation began to change rapidly in 2023–2024 as stakeholders pushed for higher-power charging to enable quick turnarounds for drivers. By 2024, DC fast chargers comprised roughly 15–20% of the UAE's public charging network, up from essentially single-digit percentages two years prior. Figure 12 illustrates this transition: the share of fast chargers (DC) in the mix rose from only ~3% in 2022 to nearly one-fifth by 2024. Notably, many of the new installations are high-power DC stations (150–350 kW) along major routes and at petrol stations, capable of delivering an 80% charge in 20–30 min. Oil company ADNOC, for instance, expanded its network from 53 fast chargers in 2023 to over 90 by mid-2024, aiming for 150+ by end of 2024. Sharjah introduced its first 100 ultra-fast chargers in 2025 as part of a city-wide program. This diversification into fast charging aligns with global trends and user expectations—drivers increasingly expect to find rapid charging options on highways and at transit hubs to minimize downtime. At the same time, moderate-speed AC stations remain vital for workplaces and home charging, so the UAE's strategy is to densify AC coverage in urban areas while phasing in DC chargers at strategic locations (highways, bus/taxi depots, etc.) in step with EV adoption.

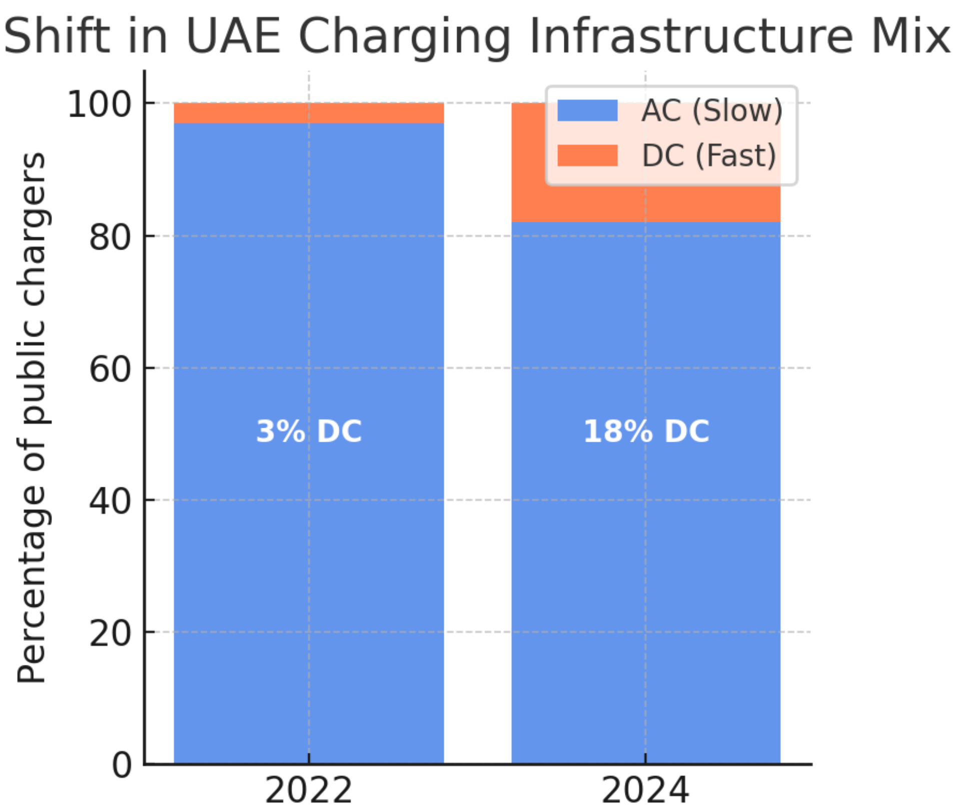

Figure 12. Composition of UAE public charging network by charger type. In 2022, the vast majority (~97%) of chargers were slower AC stations, with only ~3% being DC fast chargers.

8. EV Charging Infrastructure Costs and Policy Impacts in the UAE

Electric vehicle charging infrastructure deployment in the UAE is shaped by both economic considerations and proactive policy interventions. This section provides a detailed analysis of the cost factors associated with EV charger rollout—contrasting AC (Level 2) and DC fast-charging infrastructure—and examines how government policies, incentives, and partnerships are driving infrastructure growth. Emphasis is placed on the UAE's experience, with selective comparisons to regional trends in the GCC for context.

8.1. Infrastructure Deployment Costs: AC vs. DC Charging

The costs of establishing EV charging stations in the UAE vary widely depending on charger technology (AC versus DC) and power level. Table 8 summarizes typical cost components for Level 2 AC chargers (commonly 7–22 kW) versus DC fast chargers (50 kW and above). AC charging units are substantially cheaper to procure and install, whereas DC fast chargers involve high-end power electronics and often require significant electrical upgrades, making their upfront costs an order of magnitude higher. For instance, a commercial-grade dual 22 kW AC station might cost on the order of only a few thousand USD for the hardware, whereas a standard 50–150 kW DC fast charger unit can cost tens of thousands. Ultra-fast chargers (150–350 kW) are at the upper end of the spectrum, with equipment costs potentially exceeding $100,000. These figures exclude installation expenses, which can be substantial for DC units—often involving grid connection upgrades, transformers, and civil works—adding many tens of thousands of dollars in site preparation costs. In the GCC context, a fully installed public fast-charging station can commonly exceed $120,000 in upfront investment, whereas an AC charging post might be deployed for a fraction of that (e.g., under $15,000 total). High capital costs for fast chargers are indeed recognized as a key barrier limiting private-sector investment in charging networks.

Table 8. Typical cost components for AC Level 2 vs. DC fast-charging stations in the UAE.

Charger Type	Power Level	Hardware Unit Cost	Installation Cost (Site)	Annual O&M Cost
AC Charger (Level 2)	~7–22 kW (single/three-phase)	$1000–$10,000	$3000–$15,000	$300–$500
DC Fast Charger	50–150 kW (standard DCFC)	$30,000–$100,000+	$20,000–$50,000+	$600–$1000
DC Ultra-fast	150–350 kW (high-power)	$100,000–$200,000+	$50,000–$100,000+	$1000+

Operational and maintenance (O&M) costs also differ between AC and DC infrastructure. Basic AC chargers have relatively low maintenance needs and incur modest annual costs (often on the order of a few hundred USD per year for networking, software, and preventive maintenance). In contrast, DC fast chargers include more complex components (cooling systems, high-power converters) that require regular servicing and monitoring. Consequently, their maintenance costs can be roughly double those of AC units, reaching $600–$1000 per year per station. Additionally, electricity demand charges (fees for high peak power draw) can significantly impact the operating cost of DC fast charging stations, especially when utilization is low. These economic factors underscore why AC chargers remain the backbone of many public networks for "destination" charging, while DC chargers—despite higher costs—are strategically deployed to enable quick charging along highways and in high-traffic nodes. Public planners in the UAE have sought to strike a balance, expanding the AC network for broad coverage (e.g., at malls, offices, and residential complexes) and adding DC fast chargers to relieve range anxiety on inter-city routes and support commercial EV fleets.

Despite the higher costs, investments in DC fast charging are growing in the UAE to support long-distance travel and intensive use cases. Notably, the national oil company ADNOC has begun installing high-power chargers at its service stations, and Dubai's utility (DEWA) rolled out its first 150 kW "ultra-fast" chargers in 2022–2023. These moves align with global trends emphasizing charging speed for driver convenience. However, cost-effectiveness remains crucial—authorities are mindful that indiscriminate deployment of expensive fast chargers could lead to underutilization and wasted capital if the EV population is not yet sufficient to use them fully. Thus, the UAE's strategy has been to phase in high-speed chargers in step with EV adoption growth and concentrate them at strategic locations (highways, transit hubs, taxi depots), while continuing to densify the network of more economical AC chargers in urban areas.

Dubai and Abu Dhabi account for the majority of these stations, reflecting higher EV uptake in the major cities. By mid-2025, the nationwide charger count had roughly doubled to ~2000, and plans are in place to accelerate deployment further to meet future demand. By 2030, government and industry projections anticipate on the order of 20,000+ public charging points will be needed to support the country's EV growth (Castillo et al., 2024). Such expansion will require continued investment in both AC and DC infrastructure, highlighting the importance of cost management and strategic planning as shown in Figure 13.

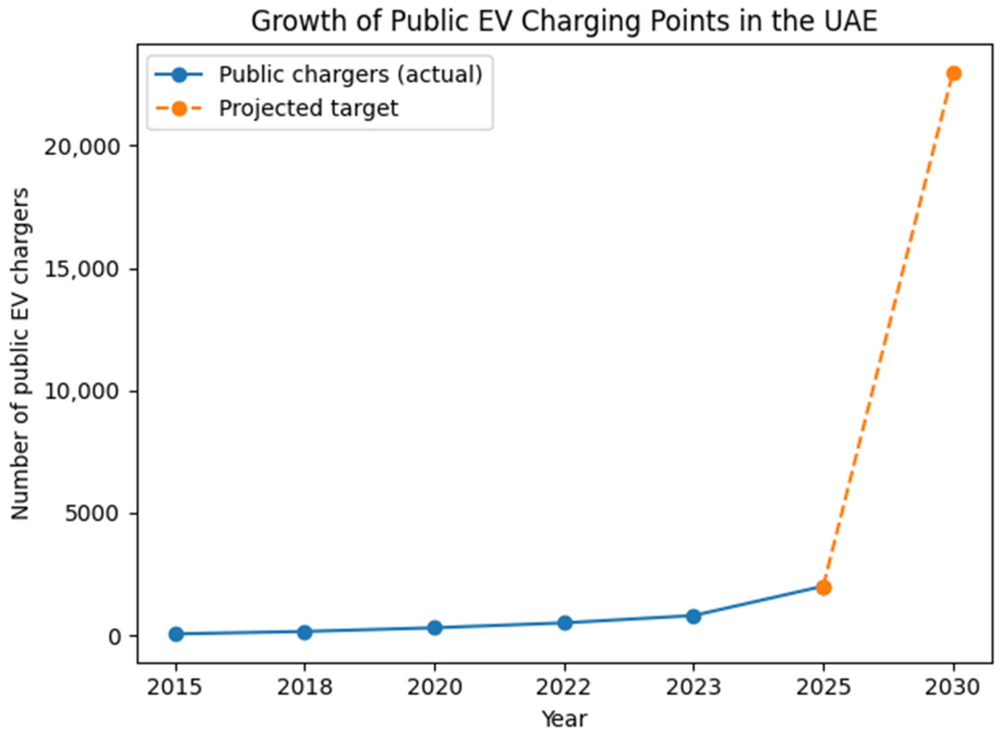

Figure 13. Growth of public EV charging points in the UAE. The UAE's public charging network has expanded rapidly from only ~200 chargers in 2018 to around 900 by 2023.

8.2. Policy Incentives and Regulatory Frameworks

Government policy in the UAE has been a catalyst for EV infrastructure development, coupling ambitious adoption targets with incentives and regulatory support. National targets set under the UAE's sustainable mobility agenda call for at least 10% of all vehicles on the road to be electric by 2030, with further aims for nearly 50% EV penetration by 2050 in line with the Net Zero 2050 strategy (UAE Government, 2023). Dubai's Green Mobility Strategy, for example, mandates that 30% of government fleet vehicles and 10% of new vehicle sales be electric or hybrid by 2030 (Dubai RTA, 2021). Abu Dhabi has likewise announced a target of 50% of new vehicles to be electric by 2040, signaling a long-term transition. To support these goals, authorities at both federal and emirate levels have rolled out a combination of financial incentives and infrastructure mandates:

- EV Incentives: UAE EV owners benefit from free or discounted vehicle registration fees, free public parking, and exemption from road tolls in many cases. For several years, Dubai also offered free charging at DEWA's public "Green Charger" stations to encourage early adoption. These incentives have lowered the total cost of ownership for EVs and spurred consumer interest. As a result, EV registrations have climbed, crossing 11,000 in Dubai by 2023 (Dubai Government, 2023) and over 15,000 in Abu Dhabi by early 2025 (ITC Abu Dhabi, 2025). The rising EV fleet, in turn, creates demand for more chargers—a positive feedback loop that justifies continued infrastructure investment.
- Public-Private Partnerships (PPPs): Given the high upfront costs of chargers (Section 8.1), the government actively encourages private sector participation to share the investment burden. In 2024, Dubai established a new regulatory framework licensing independent charge point operators (CPOs) to install and manage public chargers on a commercial basis. This opened the market to private companies and investors, under DEWA's oversight, effectively shifting from a purely government-provided network to a P model. Abu Dhabi took a similar approach with its Charge AD initiative announced in 2025, which aims to deploy 1000 new charging stations via tenders to private operators, who will handle installation, operation, and maintenance on a concession basis. Such partnerships leverage private capital and expertise—for example, oil company ADNOC and utility TAQA formed a joint venture to roll out fast chargers across Abu Dhabi, aligning with the emirate's target of 70,000 chargers by 2030 (Integrated Transport Centre, 2025). Similarly, Sharjah's city authorities have collaborated with private firms to set up charging stations at shopping centers and public parking lots. These P efforts are building a more comprehensive network than public funding alone could achieve.
- Regulations and Standards: Authorities also use regulatory mandates to ensure infrastructure keeps pace with EV growth. For instance, building codes in the UAE are being updated to require new developments

(especially large commercial or residential projects) to be EV-charger ready, installing a minimum number of charging bays or electrical capacity for future chargers. In Saudi Arabia (for regional comparison), a 2023 regulation mandates all new residential compounds include EV charging provisions, illustrating how GCC governments are integrating charging needs into urban planning. In Dubai, as noted above, a licensing regime now governs charger operators to maintain quality and safety standards, and it distinguishes between free charging services and paid public charging (each requiring a specific license). Another important aspect is the standardization of charging connectors and payment systems—UAE follows international standards (CCS/Type 2 and CHAdeMO for older vehicles), and efforts are underway to unify charging apps and RFID access across different providers, which improves user convenience and station utilization.

Policy support has also come in the form of direct government investment. The UAE government announced in 2018 a commitment of over AED 500 billion (~$136 billion) by 2050 towards clean energy and sustainable transport infrastructure (including EV charging). This massive planned expenditure underpins programs like Dubai's EV Green Charger and nationwide initiatives to electrify public transport and government fleets. Already, public funding has enabled the installation of hundreds of chargers in government facilities, petrol stations, and highway rest stops. Crucially, this has been paired with clear strategic planning: the UAE's federal and local agencies set quantitative infrastructure targets (e.g., Dubai targeting 1000 public stations by 2025, Abu Dhabi 70,000 by 2030) and are monitoring EV-to-charger ratios to guide deployment. As of 2023, the UAE had roughly 18 electric cars per public charger—comparable to leading EV markets—a sign that infrastructure roll-out has kept up with EV uptake so far.

Overall, the UAE's policy landscape reflects a multi-faceted approach: incentivize adoption on the demand side, lower barriers for infrastructure provision on the supply side, and enforce standards to ensure a reliable, interoperable charging network. This approach has positioned the UAE as the GCC leader in e-mobility readiness. The coming years (2025–2030) will test the effectiveness of these policies as EV numbers grow from the tens of thousands into the hundreds of thousands. Continued government support—through subsidies, innovative financing (green bonds, infrastructure funds), and enabling regulations—will be critical to maintain the pace of charger deployment and to keep the infrastructure-to-vehicle ratio favorable. Early evidence suggests that the UAE's model, combining strong public investment with private partnerships and clear policy signals, is succeeding in rapidly scaling up charging infrastructure. Neighboring countries like Saudi Arabia and Qatar are now drawing on similar tactics (albeit at earlier stages of EV adoption), inspired in part by the UAE's experience. The next section will conclude by distilling the insights from the UAE's EV infrastructure journey and the strategic outlook moving forward.

8.3. Cost and Policy Implications of EV Charging Infrastructure Deployment

The cost implications of this technological shift are non-trivial. High-power DC chargers are substantially more expensive than AC units—a single 150–350 kW ultra-fast charger can cost $100 k–$200 k (USD) for equipment alone, plus tens of thousands more for installation (due to heavier grid connection needs and civil works). In contrast, a typical 22 kW AC station might cost on the order of $5 k for hardware and a few thousand for installation. Despite the higher costs, UAE investors (both public and private) are ramping up DC deployments to fill critical gaps in the charging network. Authorities remain mindful of cost-effectiveness—underutilized expensive chargers would waste capital—and thus are phasing in ultra-fast stations in tandem with the growth of the EV population. The strategy focuses on targeted rollouts: for example, placing clusters of fast chargers along highways and in high-traffic locales, while continuing to add lower-cost AC chargers in residential and urban settings for routine use. This balanced approach helps ensure that infrastructure investment yields maximum benefit in terms of enabling EV miles driven and alleviating range anxiety, without stranding costly assets.

The UAE's government policies have been a catalyst for these infrastructure advances. A National Electric Vehicles Policy launched in 2023 set unified standards and a headline target of 10,000 public chargers by 2030 (recent analyses suggest an even higher number may be needed). Federal and local authorities have backed this with substantial funding commitments (e.g., hundreds of millions of AED under clean energy programs) and by opening the market to private sector participation. In Dubai, for instance, a 2024 regulatory framework introduced licensing for independent charge point operators (CPOs), encouraging companies like Tesla and international charging firms to deploy stations under the oversight of DEWA. As a result, what was once a predominantly government-provided service is shifting to a hybrid model leveraging private investment and innovation. Early signs of success include a 72% jump in Dubai's charging points during the first half of 2025 after new private CPOs began operations. Public-private partnerships (PPP) are likewise central in Abu Dhabi's approach (e.g., the joint venture E2GO between ADNOC and TAQA to roll out fast chargers, and the Charge AD program tendering stations to private operators). These efforts are expanding the charging network more rapidly than public funding alone could achieve, while also bringing international best practices and technical expertise into the UAE market.

From a regional perspective, the UAE's progress stands out. As of 2024, it accounts for the largest share of public EV chargers in the Gulf Cooperation Council (GCC) region. Neighboring countries are ramping up plans (e.g., Saudi Arabia targeting 5000 fast chargers by 2030), but currently have installed only a few hundred chargers each. The UAE's comprehensive approach—combining ambitious targets, supportive policies, and active private-sector engagement—is increasingly seen as a model for other emerging EV markets. By demonstrating that challenges such as extreme climate, range anxiety, and high infrastructure costs can be addressed through coordinated strategy, the UAE provides a blueprint for scaling EV charging ecosystems in new markets.

9. Conclusions

The development of EV charging infrastructure in the UAE represents a critical pillar of the nation's transition toward sustainable transportation and a low-carbon future. This paper has shown that while the UAE's EV adoption is now rising at an impressive pace, the successful deployment of supporting infrastructure requires a holistic, strategic approach. UAE initiatives like Abu Dhabi's Charge AD and Dubai's EV Green Charger program exemplify forward-looking frameworks that integrate public-private collaboration, standardization of technology, digital solutions (smart charging apps, unified payment systems), and user-centric policies. These programs have enabled rapid growth in charger availability and improved public confidence in EV usability, contributing directly to rising EV registration rates.

Challenges, however, persist. Ensuring an equitable distribution of chargers across both dense urban centers and suburban or highway areas remains important—the current concentration in major cities must eventually extend nationwide to support inter-city travel. Technical limitations related to battery range and the impact of fast charging on battery life call for ongoing innovation in both battery technology and charging methods (e.g., vehicle-to-grid integration, wireless charging). There are also structural hurdles, such as retrofitting charging facilities into older high-density residential buildings and balancing economic feasibility with accessibility (high-power chargers are costly and may see low initial utilization, yet they are crucial for enabling long-distance trips and fleet operations). Addressing these issues will require continuous fine-tuning of policies—for example, incentives for installing chargers in apartment complexes, or time-based pricing to discourage EVs from occupying chargers for too long.

Going forward, a unified national approach that blends dynamic policy support, technological innovation, and strategic investment is essential to sustain momentum. The UAE's federal structure has already fostered healthy competition and knowledge-sharing between emirates (Dubai and Abu Dhabi in particular), and this can be leveraged further via a coordinated national rollout plan. Key recommendations include: expanding smart-grid integration so that the electricity network can smoothly handle growing EV charging loads (and potentially draw on EV batteries for grid support), promoting interoperability and open standards across all charging operators, and maintaining a focus on user experience (reliable uptime, convenient locations, clear pricing) to maximize public trust in the system. The convergence of the UAE's clean energy commitments with its transportation electrification initiatives presents a transformative opportunity not only for emissions reduction but also for economic diversification (e.g., new green industries and jobs) and energy resilience.

In conclusion, the UAE's recent experience demonstrates that with high-level commitment and a strategic framework, it is possible to scale up EV infrastructure rapidly while balancing technological, social, and economic dimensions. The UAE is on track to emerge not only as a regional leader in e-mobility, but also as an international case study for how targeted policy and innovation can drive a successful transition to electric transportation. By continuing to address the gaps and proactively planning for future demand, the UAE can provide a roadmap for other countries aiming to develop smart, carbon-neutral transport systems in the 21st century.

Funding

This research was funded by the university of Sharjah research fund No. (24020406323).

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data used to support the findings of this study are included within the article. Additional information can be provided by the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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