# Review on Dynamic Wireless Charging for Electric Vehicle

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**Abstract -** The rising adoption of electric vehicles (EVs) has intensified the need for sustainable and efficient charging infrastructures. This paper presents a comprehensive review of solar-based EV charging stations and wireless charging systems, focusing on their potential to contribute to an eco-friendly and accessible charging solution. Solar-based charging stations leverage photovoltaic (PV) technology to generate renewable energy, reducing dependency on traditional grid power. These systems face challenges such as energy storage, variable solar output, and system efficiency, which are addressed through advanced energy management strategies like Maximum Power Point Tracking (MPPT). On the other hand, wireless charging systems, particularly inductive and resonant power transfer, offer the convenience of cable-free operation and can enhance the user experience by integrating charging seamlessly into parking and roadway infrastructure. However, issues related to alignment, power transfer efficiency, and electromagnetic interference persist. This review explores the feasibility of hybrid systems combining solar and wireless technologies, providing an in-depth analysis of their design, operational challenges, and real-world applications. The findings underscore that, while solar and wireless charging systems individually hold promise, their integration could revolutionize EV charging by offering a sustainable and flexible solution. The paper concludes by discussing ongoing research, future technological developments, and the potential environmental benefits of widespread adoption of these integrated systems, which collectively align with global renewable energy goals and sustainable urban planning initiatives.

***Keywords*—**Solar-based EV charging, Wireless charging systems, Photovoltaic (PV) technology, Inductive charging, Resonant power transfer, Energy management in EV charging, Sustainable transportation, Renewable energy integration, Electric vehicle infrastructure

## 1. INTRODUCTION

The rapid growth in electric vehicle (EV) adoption reflects a global shift towards reducing carbon emissions and enhancing energy efficiency in the transportation sector. Traditional combustion engines contribute significantly to greenhouse gas emissions, and as urban populations grow, the demand for eco-friendly alternatives is intensifying. EVs offer a cleaner, more sustainable solution to transportation. However, the widespread adoption of EVs largely depends on the availability of reliable, efficient, and sustainable charging infrastructure. As more EVs hit the roads, there is a pressing need for charging solutions that align with the global commitment to reduce environmental impact. This need has inspired innovations in renewable energy-based charging systems, especially those harnessing solar power.

As EV adoption rises, so does the strain on existing power grids, which are typically reliant on fossil fuels. Without renewable integration, EV charging risks undermining the ecological benefits that EVs provide. Integrating renewable sources like solar energy into charging networks can reduce this dependency on non-renewable resources, reinforcing the green benefits of EV adoption. Solar-powered charging stations, which are increasingly being deployed, offer a sustainable, off-grid solution adaptable to a wide range of locations—from urban centers to remote areas. These stations support environmental goals while also improving energy accessibility in areas with limited infrastructure. However, while solar power presents a promising solution, challenges remain, such as energy storage, intermittent solar availability, and high setup costs.

Solar-based EV charging stations, built on photovoltaic (PV) technology, convert sunlight into electrical energy. Depending on their design, these stations can operate independently or connect to the grid, offering flexibility in deployment. Solar stations are equipped with essential components such as solar panels, inverters, and often battery storage systems to maintain power availability even when sunlight is not optimal. Advanced energy management techniques, including Maximum Power Point Tracking (MPPT), are employed to maximize efficiency by extracting the highest possible power from solar panels. However, despite their many benefits, solar-based charging stations face significant challenges. High installation costs and the intermittent nature of solar energy, which depends on weather and daylight, limit consistent power availability and reliability.

In addition to solar solutions, wireless charging represents an innovative approach to modern EV infrastructure. Wireless charging eliminates the need for physical cables, allowing energy to transfer from a base charging pad to a receiver within the vehicle using electromagnetic fields. This approach offers several benefits, notably convenience and ease of use. Wireless charging is especially suitable for public and in-motion charging applications, where vehicles can charge automatically without the need for manual connection. Technologies like inductive and resonant power transfer enable efficient wireless energy transfer but come with their challenges. Key concerns include alignment between the charging pad and the vehicle, energy transfer efficiency, and safety considerations related to electromagnetic fields. Additionally, the costs associated with wireless infrastructure remain high, which has slowed its widespread adoption.

Hybrid solar-wireless charging systems combine the ecological benefits of solar energy with the user-friendly nature of wireless technology, offering a flexible and sustainable solution. In hybrid systems, solar power serves as the primary energy source, often supplemented by the grid when solar output is insufficient, while wireless technology facilitates an effortless charging experience. These systems are particularly suited for diverse environments, including residential areas, commercial facilities, highways, and remote regions, where traditional grid infrastructure may be weak or nonexistent. Although the potential of hybrid systems is promising, they present complex design requirements to balance energy flow and ensure system efficiency. Fluctuations in solar availability can complicate energy management, and integrating solar with wireless charging calls for advanced energy optimization strategies.

Several critical design considerations must be addressed in solar and wireless charging systems to ensure practical and efficient implementation. Efficiency and energy management are paramount, particularly in solar-based systems where environmental conditions affect performance. Techniques like MPPT enhance efficiency in these systems, while wireless charging systems must address alignment and energy transfer issues to improve overall effectiveness. Additionally, cost and scalability are essential factors; solar installations can be costly initially, and wireless systems require significant investment in infrastructure. Scaling these systems requires careful attention to affordability and design adaptability to accommodate increased vehicle volumes. Safety and electromagnetic interference (EMI) are also key considerations, particularly for wireless systems, as electromagnetic fields can interfere with nearby devices and may have health implications. Ensuring regulatory compliance and compatibility with other electronics is critical for both public and residential installations. Moreover, these systems contribute to sustainability not only through emissions reduction but also by considering material sustainability, end-of-life disposal, and maintenance requirements.

The implementation of solar-powered EV charging infrastructure is gaining momentum globally, with various projects showcasing its feasibility across climates and settings. Wireless charging, while still emerging, has seen pilot applications in buses, taxis, and other public transport systems. As research advances, trends in EV charging increasingly emphasize integrating artificial intelligence (AI) for energy management, utilizing smart grids for efficient distribution, and adopting advanced materials to enhance the efficiency and durability of both PV cells and wireless hardware. These trends illustrate a shift towards smarter, more adaptive systems designed to handle fluctuating energy demands and provide reliable service.

This review paper aims to explore the feasibility, design, and potential impact of solar-based and wireless EV charging systems. It presents an in-depth examination of solar-based charging stations, detailing their design, operational challenges, and deployment options. Following this, wireless charging technologies are discussed, with particular attention to advancements in inductive and resonant power transfer. Finally, the paper investigates the potential of hybrid solar-wireless systems, analyzing their benefits, limitations, and suitability for diverse environments. Concluding with a discussion on future research directions, this review highlights the path forward for sustainable and user-friendly EV infrastructure, contributing to the growing body of knowledge supporting renewable energy integration and sustainable urban development.

## 2. LITURATURE SURVEY

Sen et al. [1] present a dynamic solar wireless electric vehicle (EV) charging system that utilizes electromagnetic induction technology to facilitate on-the-go charging. The system is designed with copper coils embedded in roads to wirelessly transfer power to vehicles passing over them. This setup aims to mitigate range anxiety by enabling continuous charging, thus eliminating the need for frequent stops at charging stations. Results indicate that the power transfer is effective, but high infrastructure costs remain a significant barrier to widespread implementation. Additionally, there is a need for more efficient coil designs to optimize power transfer and reduce costs in dynamic setups.

Haritha et al. [2] introduce the Solar Wireless Electric Vehicle Charging System (SWEVCS) that operates using a Raspberry Pi Pico microcontroller. The system employs solar energy harvested through photovoltaic panels, which is then stored and used to wirelessly charge EVs via a boost converter and induction coils. The Raspberry Pi Pico coordinates the charging process and displays real-time updates through an LCD. While SWEVCS offers an environmentally friendly charging option, the authors identify a challenge in maintaining consistent power transfer rates, especially under varying environmental conditions, such as cloud cover and shadows, which affect solar efficiency.

Muganur et al. [3] developed an inductive power transfer system using an ESP32 microcontroller, which powers EV charging through solar panels. The setup involves converting the DC electricity from solar panels to AC, which is then wirelessly transmitted to EV batteries through inductive coupling. Results show that the system is capable of charging EVs effectively; however, sensitivity to the alignment between transmitter and receiver pads poses a limitation. The researchers suggest further refinement in the alignment mechanisms to improve efficiency.

Prasad et al. [4] propose a solar-based charging system that uses embedded inductive charging pads within road infrastructure to support high-range, uninterrupted EV charging. This system targets an extended driving range for EVs by enabling charging without requiring the vehicle to stop. While results are promising, especially for high-traffic areas, the authors note that high initial costs and infrastructure investment could delay widespread adoption. The study suggests that future research should focus on reducing costs through advancements in materials and design.

Shil [5] explores a wireless EV charging system based on coupled induction theory, which considers variables such as coil alignment, size, and distance. Using a mathematical approach, the study evaluates the effects of these factors on charging efficiency and identifies optimal coil dimensions for enhanced power transfer. While the system shows improved efficiency, Shil highlights the need for standardization across wireless charging technologies to ensure compatibility with various EV models, which remains a significant research gap.

Tutakne et al. [6] introduce a dynamic solar-powered EV charging system designed to optimize charging rates based on the battery’s state of charge. This system allows vehicles to be charged while moving, thereby extending their range and reducing dependency on stationary charging points. Although effective in terms of range extension, scalability is a challenge, especially as this setup depends on specific road layouts that might not be feasible for all locations. The authors recommend developing adaptive layouts that can integrate with various road structures.

Singh et al. [7] examine a solar wireless charging system with a focus on minimizing electromagnetic emissions, a crucial aspect for urban applications where human exposure to electromagnetic fields is a concern. The system uses a novel coil arrangement that reduces emissions while maintaining effective power transfer. Although this setup improves safety, the authors point out that more extensive testing is required across different vehicle models and operational speeds to validate its effectiveness comprehensively.

Chobe et al. [8] propose a solar-based wireless EV charging station incorporating smart monitoring for energy tracking and predictive maintenance. The system reduces dependency on grid electricity by leveraging renewable solar power and enables remote monitoring to ensure operational efficiency. While the smart monitoring feature is a notable advancement, the authors note a research gap in real-time data analytics for system optimization, which could improve the station's overall performance in diverse environmental conditions.

Nguyen et al.[9] evaluate the effectiveness of bipolar charging pads for wireless EV power transfer, achieving high efficiency and improved reliability. Despite these improvements, the study reveals interoperability issues across different EV brands, which could limit user accessibility to compatible charging stations. Further research is recommended to develop universal standards that would enable compatibility among diverse vehicle models.

Pande et al. [10] designed a bidirectional wireless charger for EVs that facilitates energy transfer both to and from the grid. This approach enhances the system's sustainability by allowing energy exchange but is limited by current grid capacities, as simultaneous charging and discharging could lead to grid overload during peak times. The study identifies grid management as a critical area for future research to fully utilize the benefits of bidirectional charging.

Rana et al. [11] introduce an eco-friendly solar and wind hybrid energy solution for EV charging stations, aiming to achieve grid independence. This setup significantly reduces reliance on non-renewable energy sources; however, inconsistent energy generation under varying weather conditions remains a limitation. The authors recommend integrating battery storage solutions to buffer against low energy generation during periods of low solar or wind availability.

Jain et al. [12] developed a solar EV charging station that employs artificial intelligence (AI)-based energy management for optimizing power distribution. AI algorithms adjust power allocation based on real-time energy demand, leading to reduced consumption. While the solution is efficient, limited testing across various EV models presents a research gap, and the authors recommend broader testing to improve generalizability.

Patel et al. [13] implement a solar-based EV charger that dynamically adjusts power levels using Internet of Things (IoT) sensors, which respond to real-time data to prolong battery life. Although effective in enhancing battery health, the system's response time needs further optimization to prevent delays that may impact charging speed.

Roy et al. [14] conducted a cost-benefit analysis of a dynamic solar EV charging system, revealing high initial costs with long-term savings. Findings suggest that government subsidies could help offset setup costs, encouraging broader adoption. The study also recommends further research into cost-reduction strategies for installation materials.

Ali et al. [15] investigate high-frequency wireless charging setups that enhance energy transfer efficiency but at a high component cost. The study highlights the trade-off between efficiency and cost, suggesting that advancements in affordable high-frequency components could address this barrier.

Das et al. [26] enhance magnetic field control in inductive wireless charging systems, resulting in safer power transfer. However, the system's adaptability to different EV models remains a limitation, underscoring the need for universal design standards.

Naik et al. [27] employ a solar and wind hybrid setup, achieving substantial reductions in emissions. Yet, low energy generation in weak wind conditions is a limitation, and battery storage integration is suggested to maintain energy availability.

Ghosh et al. [16] designed a road-integrated wireless EV charging system with mechanisms to enhance energy utilization, offering the potential for continuous on-the-go charging. However, compatibility with various EV models remains a challenge, emphasizing the need for further standardization in wireless charging designs.

Gupta et al. [17] developed an embedded system that monitors solar-powered EV charging efficiency in real-time, achieving improved accuracy in tracking energy use. Despite its benefits, the system requires additional testing across different climate conditions to verify consistency in various environments.

Ram et al. [18] utilize solar energy to charge EVs wirelessly through inductive coils embedded in roads. While the system reduces reliance on fossil fuels, energy storage and utilization efficiency issues are noted, indicating the need for further improvements in these areas.

Prakash et al. [19] present a solar-battery hybrid system for EV charging, demonstrating effective charging in sunny conditions but reduced performance during cloudy periods. This limitation calls for enhanced storage mechanisms to ensure consistent charging under variable sunlight exposure.

Desai et al. [20] propose a multi-source energy management system for EVs, combining solar and grid power to reduce grid dependency. The system efficiently manages energy flows, but challenges arise in real-time energy balancing, indicating a need for advanced energy control algorithms.

Sharma et al. [21] implement a solar EV station with adaptive power adjustments, which enhances charging efficiency. However, the authors note that validation in diverse climates is required to ensure the system's reliability across various environmental conditions.

Sundar et al. [22] optimize coil design for wireless EV charging, achieving efficient energy transfer. Nevertheless, strict alignment requirements reduce user convenience, indicating a need for research on flexible coil designs that maintain efficiency without precise alignment.

Saxena et al. [23] created a modular power transfer system for solar-based charging stations, which improves scalability and reduces setup costs. However, latency issues remain a challenge, suggesting further research into faster response times for a seamless user experience.

Kumar et al. [24] integrate AI into solar-based EV charging systems to optimize power distribution. While this increases system adaptability, fluctuating weather conditions reduce efficiency, highlighting the need for further testing to ensure robust performance.

Malik et al. [25] developed a high-efficiency power management system for renewable energy-based EV charging stations. Although effective in energy conservation, the complexity and high cost of setup pose commercialization challenges.

Patil et al. [28] enhance power transfer through a dual-layer coil design, achieving better efficiency. However, compatibility issues with some EV models indicate a need for flexible designs that can accommodate diverse vehicle architectures.

Rao et al. [29] propose a layered coil structure for solar EV chargers, which reduces energy losses. While effective, the high cost of implementation limits its feasibility for wide-scale deployment, necessitating research on cost-effective materials.

Joshi et al. [30] investigate ultra-thin coils in dynamic EV charging systems, achieving greater portability. However, more testing is needed in real-world conditions to confirm the system's reliability under various operational demands.

Table I Summary of the Literature Survey

| Sr. No. | Author(s) | Title of the Project | Published Journal Name and Year | Methodology | Key Findings | Technical Aspect |
|---|---|---|---|---|---|---|
| 1 | Sen et al. | Solar Wireless Electric Vehicle Charging System | Int. J. Res. Appl. Sci. Eng. Technol., 2023 | Electromagnetic induction with copper coils embedded in roads for dynamic charging | Effective in continuous charging, but high infrastructure costs present barriers | Dynamic EV charging through road-embedded coils |
| 2 | Haritha et al. | SWEVCS: Solar Wireless Electric Vehicle Charging System | Journal of Engineering Sciences, 2023 | Uses Raspberry Pi Pico with solar panels and boost converter for wireless EV charging | Reliable but variable power transfer rates due to environmental factors | Microcontroller-based power management system |
| 3 | Muganur et al. | Solar Wireless EV Charging System Using ESP32 | Int. J. Res. Publ. Rev., 2023 | Inductive power transfer with ESP32, DC to AC conversion from solar panels | Efficient wireless charging but affected by alignment between pads | ESP32 microcontroller for wireless inductive charging |
| 4 | Prasad et al. | Solar Wireless Electric Vehicle Charging System | Int. J. Sci. Res. Eng. Manag., 2022 | Inductive charging pads integrated within road infrastructure | High potential for extended EV range without stopping, though initial setup costs are high | Road-integrated inductive charging |
| 5 | Shil | Solar Wireless EV Charging System | Middle East College Student Research Conf., 2023 | Coupled induction theory with coil alignment optimization | Improved charging efficiency with optimal coil dimensions, but standardization is needed across EV models | Coil alignment for optimized power transfer |
| 6 | Tutakne et al. | Solar-Based Wireless Charging for EV | Int. Res. J. Modernization Eng. Technol. Sci., 2023 | Dynamic charging using solar energy and adaptive charging rates based on battery status | Range extension achieved, but layout limitations affect scalability | Adaptive charging rates based on battery level |
| 7 | Singh et al. | Solar Wireless Charging with Electromagnetic Emissions Reduction | Eur. Chem. Bull., 2023 | Novel coil arrangement to reduce electromagnetic emissions | Enhanced safety with reduced emissions; requires further testing across various EV models | Electromagnetic safety and emission reduction |
| 8 | Chobe et al. | Solar-Based Wireless Charging Station for EV | J. Electrical Systems, 2024 | Smart monitoring with solar power, predictive maintenance features for EV charging | Reduces grid dependency; noted gap in real-time data analytics for optimization | Remote monitoring and predictive maintenance integration |
| 9 | Nguyen et al. | Feasibility Study on Bipolar Pads for EV Chargers | Int. J. Power Electron., 2020 | Evaluation of bipolar pads for wireless power transfer to EVs | Achieves high efficiency; interoperability issues across EV brands | Bipolar pad design for EV charging |
| 10 | Pande et al. | Bidirectional Battery Charger for EVs | Int. J. Electr. Power Energy Syst., 2021 | Bidirectional energy transfer to and from the grid for improved sustainability | Limited by current grid capacities; could overload during peak usage | Bidirectional grid and EV energy transfer |
| 11 | Rana et al. | Hybrid Solar-Wind Energy Solution for EV | Renew. Energy Res., 2022 | Hybrid solar and wind energy setup for grid independence in | Reduces reliance on non-renewables; inconsistent generation | Dual energy source (solar and wind) for EV |

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| | | Charging | | EV charging stations | under varying weather | charging |
| 12 | Jain et al. | AI-Based Energy Management in Solar EV Charging | IEEE Trans. Smart Grid, 2023 | AI algorithms for real-time power distribution in solar EV charging | Reduced energy consumption; limited testing across EV models | AI-driven power optimization |
| 13 | Patel et al. | Dynamic Power Adjustment in Solar EV Charging | Int. J. Electr. Comput. Eng., 2023 | IoT sensors for real-time power level adjustments | Improved battery life; response time requires further optimization | IoT-based adaptive power control |
| 14 | Roy et al. | Cost-Benefit Analysis of Dynamic Solar EV Charging | J. Clean Energy Prod., 2023 | Economic analysis of dynamic EV charging systems | High initial costs with long-term savings; government subsidies could help | Economic feasibility of dynamic charging |
| 15 | Ali et al. | High-Frequency Wireless EV Charging | Renew. Energy Environ. Sustain., 2023 | High-frequency components for efficient wireless energy transfer | Effective but expensive due to high-frequency component costs | High-frequency wireless charging components |
| 16 | Ghosh et al. | Road-Integrated Wireless EV Charging System | Int. J. Innov. Technol. Explor. Eng., 2023 | Road-integrated inductive charging with optimized energy transfer | Compatibility with diverse EV models remains a challenge | Road-based wireless charging infrastructure |
| 17 | Gupta et al. | Embedded Real-Time Monitoring of Solar EV Charging | Int. J. Electr. Power Energy Syst., 2023 | Embedded system to monitor charging efficiency | Improved tracking accuracy; requires further testing in different climates | Embedded real-time monitoring |
| 18 | Ram et al. | Inductive Charging for Solar-Powered EVs | Int. J. Electr. Power Energy Syst., 2023 | Inductive coils for road-embedded wireless charging | Energy storage and utilization efficiency require improvement | Road-embedded inductive charging |
| 19 | Prakash et al. | Solar-Battery Hybrid System for EV Charging | Energy Procedia, 2023 | Hybrid system using solar panels and battery storage for EV charging | Effective in sunny conditions; performance declines in cloudy weather | Hybrid energy source for EV charging |
| 20 | Desai et al. | Multi-Source Energy Management in EV Charging | IEEE Access, 2023 | Combination of solar and grid power for energy flow management | Reduced grid dependency; real-time energy balancing challenges | Multi-source energy management |
| 21 | Sharma et al. | Adaptive Solar EV Charging Station | IEEE Access, 2023 | Adaptive power adjustments for efficient EV charging | Effective but needs validation in various climates | Adaptive solar energy adjustments |
| 22 | Sundar et al. | Optimized Coil Design for Wireless EV Charging | Int. J. Sci. Eng. Res., 2023 | Coil design optimization for better wireless power transfer | Efficiency improved, but alignment requirements reduce convenience | Optimized coil design for power transfer |
| 23 | Saxena et al. | Modular Power Transfer in Solar-Based EV Charging | IEEE Trans. Ind. Electron., 2023 | Modular design for scalable power transfer | Good scalability but latency issues observed | Modular system for scalable EV charging |
| 24 | Kumar et al. | AI-Optimized Power Distribution in Solar EV Charging | IEEE Trans. Smart Grid, 2023 | AI-based power distribution to handle fluctuating energy generation | Improved adaptability; inconsistent performance in fluctuating weather | AI-driven power management |
| 25 | Malik et al. | High-Efficiency Renewable Power Management for EVs | Renew. Sustain. Energy Rev., 2023 | Power management system using renewable energy sources for EV charging | High setup cost limits commercial viability | Renewable energy management |
| 26 | Das et al. | Enhanced Magnetic Field | Renew. Energy, 2023 | Enhanced control over magnetic fields | Improved safety but lacks adaptability for | Magnetic field control for safety |

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| | | Control in Inductive Charging | | for safer wireless charging | diverse EV models | |
| 27 | Naik et al. | Solar and Wind Hybrid Solution for EV Charging | Energy Reports, 2023 | Hybrid solar-wind setup with battery storage for reliability | Reduced emissions; inconsistent generation during low wind conditions | Hybrid energy solution with storage |
| 28 | Patil et al. | Dual-Layer Coil Design for Improved Power Transfer | IEEE Trans. Power Electron., 2023 | Dual-layer coil setup for increased wireless transfer efficiency | Effective but needs compatibility with various EV architectures | Dual-layer coil for enhanced efficiency |
| 29 | Rao et al. | Layered Coil Structure for Solar EV Chargers | IEEE Access, 2023 | Layered coil design for minimizing energy loss | Costly setup limits large-scale application | Layered coil design for energy efficiency |
| 30 | Joshi et al. | Ultra-Thin Coils for Dynamic EV Charging | IEEE Trans. Magn., 2023 | Ultra-thin coil design for portable and dynamic EV charging | Portability enhanced but needs real-world testing | Ultra-thin coil technology for dynamic charging |

## 3. SUMMARY OF THE LITERATURE REVIEW

Wireless Electric Vehicle Charging (WEVC) has emerged as a transformative solution to meet the growing demand for sustainable, efficient, and user-friendly electric vehicle (EV) infrastructure. Traditional plug-in charging, while effective, has limitations regarding user convenience and infrastructure scalability, particularly in dense urban settings. WEVC technology, which relies on advanced wireless power transfer (WPT) mechanisms such as inductive, capacitive, and magnetic resonance coupling, provides a seamless, contactless charging experience that could simplify EV usage and maintenance. However, for WEVC to become a genuinely eco-friendly alternative, it requires integration with renewable energy sources to reduce dependency on non-renewable power. Vertical Axis Wind Turbines (VAWTs) offer a compact, efficient, and adaptable renewable energy solution well-suited to urban environments, where space is limited and environmental considerations are paramount. This section delves into the advancements in WEVC and VAWT technologies, their potential synergies, and the technical and environmental challenges of combining these systems to establish a sustainable, urban EV charging infrastructure. Through an analysis of recent innovations, this section provides insight into how these technologies can be harmonized to create an efficient, renewable-powered EV ecosystem for future cities.

## 4. DISCUSSION

The reviewed literature highlights a range of innovative approaches for developing solar-powered wireless electric vehicle (EV) charging systems, revealing both technological advancements and persistent challenges. Dynamic charging, where EVs can charge while in motion, emerges as a promising solution to address range anxiety and reduce reliance on traditional charging stations. However, studies indicate that the high infrastructure costs associated with embedding charging coils into roadways could hinder widespread implementation without substantial investment and public-private support. Additionally, effective energy transfer in dynamic systems is sensitive to coil alignment, necessitating further research to enhance robustness. Beyond dynamic charging, AI and IoT-based energy management systems demonstrate potential for optimizing charging efficiency by adapting power distribution in real-time, as explored in several studies. While these systems improve battery longevity and reduce energy waste, they introduce complexity and costs related to real-time data processing and sensor networks, which may impact their long-term viability. Innovations in coil design, such as dual-layer and optimized structures, significantly enhance power transfer efficiency and safety by minimizing electromagnetic emissions. Yet, achieving universal compatibility with diverse EV models remains a challenge, underscoring the need for standardization efforts to facilitate widespread adoption. Hybrid systems that integrate solar and wind energy show promise in reducing grid dependency, but variability in energy generation due to weather fluctuations limits their reliability. Incorporating battery storage could improve consistency, though at an additional cost. Lastly, while solar-powered wireless charging systems offer environmental and long-term economic benefits, initial setup costs remain a barrier. Studies emphasize that government incentives and subsidies could play a pivotal role in offsetting these expenses, promoting broader adoption. Overall, while substantial progress has been made, further research into cost-effective designs, compatibility, and regulatory standards will be essential to fully realize the potential of solar-powered wireless EV charging systems.

## 5. CONCLUSION

The literature on solar-powered wireless electric vehicle (EV) charging systems reflects significant strides in addressing the limitations of conventional charging infrastructure through innovative technologies such as dynamic charging, AI-driven energy management, and hybrid solar-wind setups. Dynamic charging solutions, with embedded coils in roadways, present a promising approach to alleviate range anxiety by enabling continuous charging for EVs. AI and IoT technologies further enhance efficiency by optimizing power distribution based on real-time data, while advanced coil designs improve transfer efficiency and reduce electromagnetic emissions. Despite these advancements, challenges remain, including high initial infrastructure costs, compatibility issues across different EV models, and energy variability in hybrid systems. For widespread implementation, government incentives and standardized designs will be essential to overcome these barriers, promoting sustainable EV charging that aligns with environmental goals and user convenience.

Future research should focus on developing cost-effective materials and scalable designs for dynamic and wireless EV charging systems, making them more accessible for large-scale deployment. Enhancing coil alignment mechanisms and exploring universal standards for coil designs will help improve compatibility across diverse EV models. Additionally, integrating robust energy storage solutions within hybrid solar-wind systems could mitigate weather-related energy inconsistencies, offering a more reliable energy source. Expanding the use of AI and IoT in EV charging systems will enhance real-time adaptability, but further work is needed to simplify these technologies and reduce associated costs. Cross-disciplinary collaborations between government, industry, and academia will be crucial to advancing regulatory frameworks, financial incentives, and research innovations, ultimately accelerating the adoption of sustainable, grid-independent charging infrastructures for electric vehicles.

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