Design of Wireless Charging for Electric Vehicles

Dr. Dileep J
Assistant Professor, Dept. of ECE
K. S. School of Engineering & Management
Bengaluru, India

Dr. Kishore M
Associate Professor, Dept. of ECE
K. S. School of Engineering & Management
Bengaluru, India

Dr. K Senthil Babu
Professor & Head, Dept. of ECE
K. S. School of Engineering & Management
Bengaluru, India

***Abstract*— Most Vehicles on the road today are powered by internal combustion engines. These engines produce large amounts of carbon emissions that are harmful to the environment as they run using fuels such as gasoline and diesel. Electric vehicles, on the other hand, offer an attractive substitute as they run entirely on batteries and produce no emissions, making them incredibly environmental friendly transportation. One major drawback of electric vehicles is the need to frequently charge their batteries, which can be inconvenient and time consuming with the current wire-based charging systems. Wireless charging systems remove the inconvenience to plug in the device to be charged when compared with the conventional wired charging systems.**

This paper aims to develop and demonstrate the feasibility of a Dynamic Wireless Charging for Electric Vehicles that could help to reduce reliance on fossil fuels and make electric vehicles more accessible and user-friendly. This referred to as in-motion charging is different from the conventional charging technologies as it enables charging the EV battery while driving in the transportation network. Earlier research is focused on the plug-in and conductive solutions for charging the EVs and addressed the challenges of integrating this technology into electricity networks. Plug-in EVs have limited travel range and require large and heavy batteries. Therefore, conductive charging strategies require long waiting time that limits the applicability of EVs compared to gasoline-powered vehicles.

Keywords — Inverter, Battery, RFID Reader, Primary Coil, Secondary Coil, ESP32 Module

I. INTRODUCTION

More recent research efforts introduced wireless or inductive charging solutions that enable in-motion charging of the EVs which makes EV more favourable for the daily use of many drivers Earlier publications addressed the quantified potential benefits and challenges of wireless charging the power electronic interfaces utilized for this technology WCS placement and battery sizing of the EVs with wireless charging technology. The main advantages of wireless charging technology include increasing the travel range, reducing the battery size and mitigating the prolonged waiting time for charging. Such advantages enhance the economic and environmental benefits as well as the adoption rates of EVs in the transportation networks.

Dynamic Wireless charging – also referred to as in-motion charging is different from the conventional charging technologies as it enables charging the EV battery while driving in the transportation network. Therefore, the electricity demand for wirelessly charging the EVs is determined by the traffic volume in the transportation network and the decisions made for charging the EVs as they travel over the charging stations. Therefore, unlike the conventional plug-in charging solutions, wireless charging technology underlines the interdependence between the traffic routing and the EVs‟‟ charging strategies. The EV routing determines the electricity demand at different WCS, which in turn, would affect the electricity charging prices at these stations. Therefore, as the number of EVs with wireless charging capabilities increase, the characteristics of the demand imposed by the wireless charging of EV the day-ahead operation of the electricity network.

In this paper, the proposed decentralized approach addresses the interaction between the electricity and transportation networks by capturing the imposed wireless charging demand which is further determined by the traffic flow pattern and the price of electricity. Charging an EV while in motion is called dynamic wireless charging. A typical dynamic wireless charging EV is a pure, battery-only EV that takes its electrical charge in motion, remotely, from a wireless charger installed underneath the road surface. Roads capable of supplying electric power to wireless charging EVs are called electrified roads or charging lanes. Stationary wireless charging makes the charging process safer and more convenient. However, in terms of charging time, frequency, the operation of the vehicle, and charging station allocation, stationary charging is not significantly different from conventional plug-in conductive charging. Dynamic charging, also known as in-motion charging, for electric vehicles (EVs) requires a combination of infrastructure and vehicle-side components.

Road infrastructure needs to incorporate embedded charging coils, while EVs require specific receiving coils and related electronics. Furthermore, robust power management systems and safety measures are crucial for reliable and efficient operation. Electric Vehicles (EVs) have specific technical requirements to ensure safe and efficient operation. These include robust battery management systems, reliable charging infrastructure, and adherence to safety standards. In contrast, dynamic wireless charging enables the EVs battery to be charged while in operation. This capability has raised new operations and infrastructural design issues that had never been raised for conventional plug-in EVs. It should also be stated that although the term wireless charging EV suggests a single vehicle unit, it should be understood as a system comprised of EVs and the charging infrastructure. Further terminological and categorical distinctions are discussed in subsequent sections.

A. PROBLEM STATEMENT

- Electric vehicles currently depend on stationary charging stations, leading to long charging times and reduced travel convenience.
- EVs require large onboard batteries for long-distance travel, increasing vehicle weight, cost, and reducing overall efficiency.

- Static charging infrastructure creates congestion, especially during peak hours, and adds stress to the power grid.
- Existing charging methods interrupt the driving experience and are not suitable for continuous long-distance mobility.
- There is a need for a system that can charge EVs while in motion to improve range and reduce battery dependency.
- Dynamic wireless charging presents challenges such as maintaining power transfer efficiency, coil alignment, road integration, and system cost.
- The project aims to address these challenges by developing an inductive charging system installed under the road to deliver energy to EVs as they move.

B. OBJECTIVES

- To design and develop a dynamic wireless charging system that enables electric vehicles (EVs) to charge while moving on the road.
- To utilize inductive power transfer (IPT) technology for efficient wireless energy transmission between road-embedded coils and vehicle-mounted receiver coils.
- To integrate photovoltaic (PV) units as the primary energy source for powering the charging lanes, promoting clean and renewable energy use.
- To improve power transfer efficiency (PTE) by optimizing the transmitter and receiver coil design.
- To analyze and reduce coil misalignment issues that occur due to vehicle movement, varying speeds, and uneven road conditions.
- To demonstrate continuous charging capability that helps reduce the need for large onboard EV batteries.
- To ensure safe, reliable, and stable power delivery during vehicle motion through proper compensation and converter circuitry.
- To evaluate system performance under different operating conditions and highlight benefits for long-distance travel on highways.

C. SCOPE OF THE PROJECT

- Development of a dynamic wireless charging system that allows electric vehicles to receive power while moving, eliminating the need for frequent stops at charging stations.
- Design and optimization of transmitter and receiver coils, ensuring efficient power transfer over varying distances and vehicle positions.
- Integration of photovoltaic (PV) units to supply clean and renewable energy for powering the charging lanes, reducing dependence on conventional grid electricity.
- Implementation of high-frequency converters and compensation circuits to improve overall system performance and maintain stable charging during vehicle motion.
- Study of coil misalignment and power transfer variations caused by different vehicle speeds, road conditions, and environmental factors.
- Analysis of system efficiency and feasibility for real-time highway applications, focusing on long-distance EV travel.
- Assessment of battery support and storage requirements for maintaining continuous power availability from PV-based charging lanes.
- Evaluation of environmental and economic benefits, including reduced carbon emissions and lower operating costs for EV users.

Gallium Nitride (GaN) based High-Power Multilevel H-Bridge Inverter for Wireless Power Transfer of Electric Vehicles Javad Chevinly, Shervin Salehi Rad, Elias Nadi, Bogdan Proca, John Wolgemuth, Anthony Calabro, Hua Zhang, Fei Lu (2024). This study presents the implementation of a high power GaN-based multilevel H-bridge inverter for wireless power transfer in EVs. The modular inverter delivers low-distortion excitation voltage to charging coils, validated through LTspice simulations and experimental results at 85 kHz frequency, demonstrating improved efficiency and reduced harmonic components [1].

Dynamic Wireless Charging Performance Enhancement for Electric Vehicles: Mutual Inductance, Power Transfer Capability, and Efficiency. Kantipudi V. V. S. R. Chowdary, Kundan Kumar, Byomkesh Nayak, Abhay Kumar, Manuele Bertoluzzo (2023). This paper investigates the enhancement of DWC performance by analyzing mutual inductance, power transfer capability, and efficiency. The study includes experimental analysis of various coil configurations and compensation topologies, aiming to optimize the wireless charging system’s performance metrics [2].

Optimal Deployment of Dynamic Wireless Charging Lanes for Electric Vehicles Considering the Battery Charging Rate Jun Du, Mingyang Pei, Bin Jia, Pan Wu (2022). The authors propose a two-stage optimization model for deploying DWC lanes, considering battery charging rates. The model includes a mixed-integer linear programming approach to determine optimal locations and lengths of charging lanes, validated through a case study on a freeway in Guangdong Province, China [3].

Precise Coil Alignment for Dynamic Wireless Charging of Electric Vehicles with RFID Sensing. Haijian Sun, Xiang Ma, Rose Qingyang Hu, Randy Christensen (2023). This research introduces an RFID-based coil alignment system using coherent phase detection and maximum likelihood estimation algorithms. The system achieves sub-10 cm accuracy in lateral and vertical misalignment estimates, enhancing the efficiency of dynamic wireless power transfer [4].

Optimization of Dynamic Wireless Charging Systems and Economic Feasibility Assessment of Electrified Roads. Kuanrong Qiu, Hajo Ribberink, EvgueniyEntchev (2025). The study assesses the economic feasibility of DWC systems using a levelized cost metric. It demonstrates that well designed intermittent DWC systems are cost-effective, particularly for long-haul truck transport, and includes sensitivity analysis to identify impactful parameters [5].

The Power Control and Efficiency Optimization Strategy of Dynamic Wireless Charging System for Multiple Electric

Vehicles. Zhang M., Zhang H., Tao W., Yang Y., Sang Y. (2024). This paper proposes a power control and efficiency optimization strategy for DWC systems serving multiple EVs. It considers factors like EV speed, power supply capacity, and safe braking distance, achieving a maximum efficiency of 91.79% under varying load resistances [6].

LSTM-Based Adaptive Vehicle Position Control for Dynamic Wireless Charging Lokesh Chandra Das, Dipankar Dasgupta, Myounggyu Won (2022). The authors Develop an LSTM-based vehicle motion control system to maximize charging efficiency in DWC. The system predicts optimal lateral positions for electromagnetic strength and adjusts vehicle motion accordingly, achieving up to 162.3% higher efficiency compared to traditional methods [7].

A Dynamic Wireless Charging System Based on Transmitter Module Composed of Coplanar Double Bipolar Pads with Hybrid Compensation Topology. Nenghong Xia, Mengqi Chen, Yimin Zhu (2023). This study designs a DWC System using coplanar double bipolar pads with a hybrid compensation topology. The system aims to improve power transfer efficiency and reduces sensitivity to misalignment, validated through simulations and experimental results [8].

Design of a Wireless Charging Vehicle Based on Autonomous Driving Technology. Zhekai Zhong, Zhisheng Wu, Xi'ai Chen (2023). The paper integrates Autonomous driving technology with wireless charging systems in EVs. It focuses on the design and implementation of a vehicle capable of aligning itself with charging infrastructure, enhancing the practicality of DWC systems [9].

Dynamic Wireless Charging of Electric Vehicles Using PV Units in Highways. Tarek F. Megahed, Doaa-Eman A. Mansour, Hossam El-Hady, Islam A. Hassan, Mohamed F. Khalil, Ahmed Fathy, Dina Nabil (2024). This study presents a comprehensive approach to dynamic wireless charging (DWC) for electric vehicles (EVs) by integrating photovoltaic (PV) units along highways. The system features a novel coil design and adaptive hardware to enhance power transfer efficiency (PTE) and mitigate coil misalignment. Key contributions include the optimization of transmitter and receiver coils, compensation circuits, and high-frequency inverters/converters using simulation tools. Experimental validation demonstrated a PTE exceeding 90.7%, with successful charging of EVs over a 1 km stretch at various speeds. The integration of renewable PV power and battery storage supports sustainable and efficient DWC infrastructure [10].

IoT Integrated Dynamic Wireless Charging System for Electric Vehicle with Authentication and Billing. Pangedaiah Bezawada, V. Shiva, D. Kamakshi, Sandeep V. Venkat (2024). This Paper introduces an IoT-integrated dynamic wireless charging system for EVs, incorporating authentication and billing mechanisms. The system offers two charging options: 100 rupees for 100mW and 200 rupees for 200mW, selectable via a mobile application. Real-time updates on power usage and remaining balance are provided to users. The integration of wireless power transmitting coils with IoT control ensures secure and customized charging experiences, promoting sustainable mobility [11].

Advancements in Dynamic Wireless Power Transfer for EVs. Dynamic Wireless Power Transfer (DWPT) enables electric vehicles to charge while in motion using road-embedded transmitter coils and onboard receivers. Early research explored inductive coupling, coil alignment, and compensation topologies to achieve stable power transfer. Later advances introduced misalignment-tolerant coil structures such as Double-D pads and multi-coil arrays to improve power efficiency during vehicle motion. High-frequency resonant converters and adaptive tuning circuits were developed to maintain high efficiency across varying speeds and air gaps. Recent studies highlight successful pilot projects for buses and heavy vehicles, showing benefits like extended driving range and reduced battery size. However, high installation cost, road durability issues, and electromagnetic safety compliance remain major challenges for large-scale deployment [12].

II. PROPOSED METHODOLOGY

1. Power Sources: Solar Panel and Wind Mill

Solar Panel: Converts sunlight (solar energy) directly into DC (Direct Current) electricity using the photovoltaic effect. Each cell generates around 0.5–0.6V, and many are connected in series/parallel to produce usable voltage and current. Output is DC, but not constant — it varies with sunlight intensity, temperature, and angle of the panel.

Wind Mill: Converts kinetic energy of wind into mechanical rotation, which drives a generator. The generator produces AC (Alternating Current) — often variable frequency AC because wind speed changes. This AC is passed through a rectifier circuit to convert it into DC so it can be stored or used with solar power.

Both solar and wind power are renewable sources, and their outputs are combined as DC after conversion and used as the main energy input for the system.

2. LM317 Micro Inverter: The LM317 is a voltage regulator IC used to maintain a constant DC output voltage. It acts as a micro inverter/regulator in your system, ensuring that the voltage from the solar and wind sources is adjusted to a safe level suitable for charging the battery. It prevents voltage fluctuations and ensures stable charging of the battery. Converts variable DC (from sources) into a regulated DC voltage for charging the storage battery.

3. Battery: The battery stores the DC energy produced by the renewable sources. It serves as the main power bank of the system, supplying energy when solar or wind sources are unavailable (like during nighttime or low wind).The battery provides continuous DC power to the regulator, microcontroller, and other components. Therefore it acts as an energy storage unit and ensures uninterrupted power supply.

4. Regulator: The regulator maintains a stable DC output voltage from the battery to the primary coil. This ensures a constant current flow, which is essential for efficient electromagnetic induction between coils. Without this regulator, the varying battery voltage could reduce charging

efficiency or cause overheating. Supplies steady DC power to the primary coil for wireless energy transfer.

5. Primary Coil: The primary coil is placed under the road surface or charging pad. When current flows through it, it generates an alternating magnetic field (using high-frequency AC created by a driver circuit or inverter stage).This magnetic field is the key to wireless power transfer. Converts electrical energy into a magnetic field for wireless transmission to the vehicle's coil.

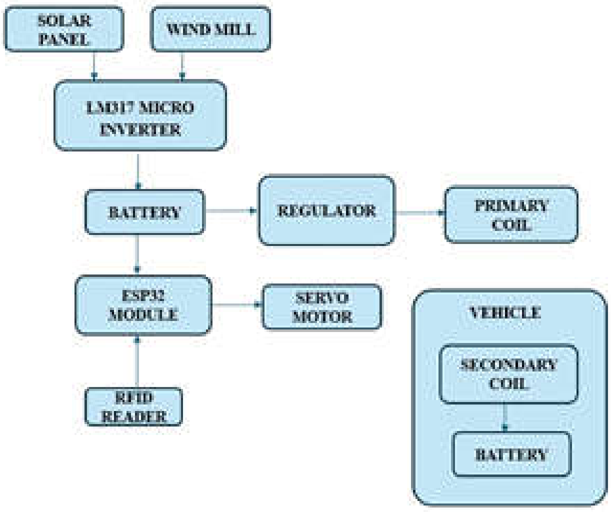


Fig. 1: Proposed Block Diagram

6. Vehicle Unit

Inside the vehicle, there are two main parts:

1. Secondary Coil
2. Vehicle Battery

Secondary Coil:

Mounted at the bottom of the vehicle. When it comes within range of the primary coil's magnetic field, it receives power through electromagnetic induction. The alternating magnetic field induces an AC voltage in the secondary coil. This AC voltage is then rectified to DC to charge the vehicle's battery.

Vehicle Battery:

The secondary battery stores the energy received from the secondary coil. This battery powers the vehicle's motor and electrical systems, enabling the vehicle to charge even while moving or stopped. Transfers power wirelessly from the road (primary coil) to the vehicle (secondary coil) and charges the onboard battery dynamically.

7. Microcontroller

The microcontroller acts as the central control unit of the system. It monitors inputs from the RFID reader and controls the servo motor. When an authorized vehicle is detected by the RFID reader, the microcontroller activates the system to enable charging. It ensures safe operation, prevents unauthorized usage, and may also control timing, switching, or indication circuits. Handles decision-making and system control based on RFID authentication.

8. RFID Reader

RFID (Radio Frequency Identification) is used to identify authorized vehicles. The reader scans for RFID tags attached to vehicles. When a valid tag is detected, it sends a signal to the microcontroller. This ensures that only registered vehicles can access wireless charging, preventing misuse. Provides security and authentication to the charging system.

9. Servo Motor

The servo motor performs mechanical operations based on the microcontroller's commands. For example: It can move or align the charging pad. It can activate/deactivate the coil setup. It ensures proper positioning of the primary coil or shield when a vehicle is detected. It helps achieve automatic operation and improves the system's accuracy. Assists in automatic physical movement or activation controlled by the microcontroller.

III. FLOWCHART AND IMPLEMENTATION

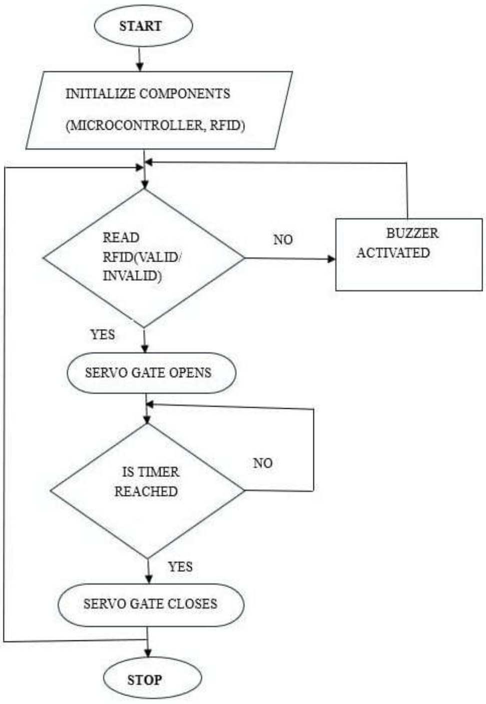


Fig 2: Flowchart

The flowchart represents the working process of the RFID-based automated gate control system. The operation begins with the initialization of all essential components, including the microcontroller, RFID reader, servo motor, buzzer, and timer. Once the system is initialized, the RFID reader continuously scans for a tag. When a tag is detected, the system verifies whether it is valid or invalid.

If the RFID tag is invalid, the system immediately activates the buzzer to indicate unauthorized access. After buzzing, the system returns to the RFID reading stage and waits for the next card.

If the RFID tag is valid, the system sends a control signal to the servo motor, which rotates to open the gate. After the gate opens, a timer is started to allow the user sufficient time to pass. The system repeatedly checks whether the timer has reached the preset duration.

Once the timer period is completed, the servo motor is triggered again to close the gate, ensuring proper security and controlled access. The operation then reaches the stop point or resets to the RFID reading state for the next user. This flowchart clearly demonstrates a secure and automated access mechanism using RFID authentication, timing control, and servo-motor actuation.

IV. RESULTS AND DISCUSSION

The hybrid renewable energy charging system was evaluated using two main power sources: a solar panel and a windmill generator. The solar panel produced a steady output of 6V, while the windmill generated approximately 6V at around 100 RPM, with the exact output depending on wind speed. A 12V / 7Ah battery was used as the storage unit to measure charging performance.

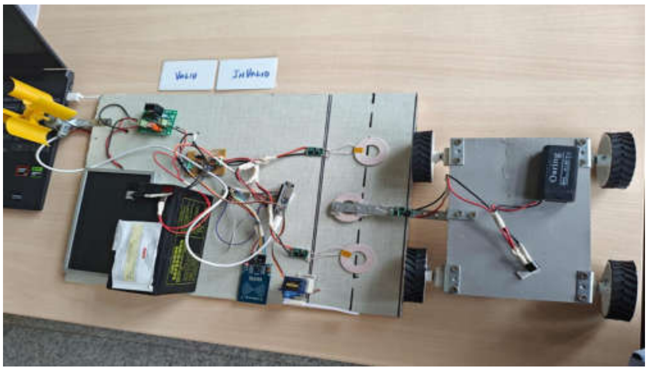


Fig 3: Proposed Model

During testing, the solar panel alone required about 14 hours to charge the 12V battery due to limited voltage and dependence on sunlight intensity. The windmill source charged the same battery in approximately 10 hours, showing better efficiency when adequate wind conditions were present. When both solar and wind sources were used together, the charging duration extended to 2–3 days, as the system operated under minimum voltage conditions depending on variations in sunlight and wind availability.

Fig 4: Solar Measured Value

The wireless charging coil in the setup was not used as a power source, but only as the output transfer element for transmitting the stored energy from the battery to the load. It successfully delivered 5V at the output side for demonstration purposes.

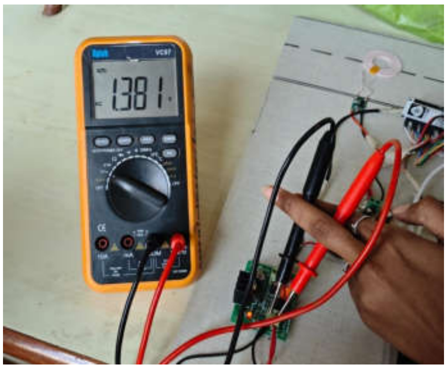
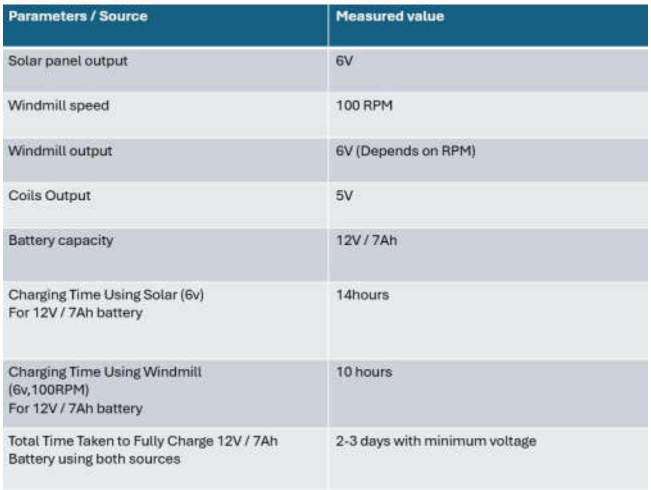


Fig 5: Windmill Measured Value

Overall, the results confirm that the hybrid system is capable of harvesting renewable energy from multiple environmental sources, storing it in a battery, and delivering it wirelessly through the coil. Although the charging time varies due to environmental fluctuations, the system effectively demonstrates continuous and sustainable power transfer for small-scale applications.

Table 1: Features of Proposed Model



Parameters / Source	Measured value
Solar panel output	6V
Windmill speed	100 RPM
Windmill output	6V (Depends on RPM)
Coils Output	5V
Battery capacity	12V / 7Ah
Charging Time Using Solar (6v) For 12V / 7Ah battery	14hours
Charging Time Using Windmill (6v,100RPM) For 12V / 7Ah battery	10 hours
Total Time Taken to Fully Charge 12V / 7Ah Battery using both sources	2-3 days with minimum voltage

CONCLUSION AND FUTUREWORK

This paper successfully demonstrates a working model of Dynamic Wireless Charging of Electric Vehicles using Photovoltaic (PV) units, proving that renewable solar energy can be effectively used to power electric vehicles while they are in motion. The system integrates PV-based energy generation with inductive power transfer, showing how vehicles can receive continuous energy without stopping at charging stations. This work highlights the feasibility of reducing range anxiety, improving energy efficiency, and supporting greener transportation.

The key contributions of this project include the development of a functional wireless charging setup, an optimized coil arrangement for better power transfer, and the utilization of PV units as a sustainable energy source. The findings show that dynamic charging can reduce dependence on grid-based charging infrastructure, support long-distance travel, and reduce carbon emissions by relying on clean solar energy.

However, the current project has certain limitations. The prototype operates only on a small scale with limited charging distance and lower power levels. Real-world challenges such as coil misalignment, varying vehicle speeds, environmental conditions, and long-distance energy transfer were not fully addressed. The system also depends heavily on the availability of sunlight, which may fluctuate due to weather or time of day.

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