Heliomotors: A Comprehensive Ecosystem for Multifunctional Solar-power ed e-Vehicle

MD Zobaer Hossain Bhuiyan
Electrical and Computer Engineering
North South University
Dhaka, Bangladesh
zobaer.bhuiyan@northsouth.edu

S.H.M. Ali Bin Rashid
Department of Computer Science and Engineering
North South University
mali.rashid@northsouth.edu

Md. Baker
Department of Electrical and Computer Engineering
North South University
Dhaka, Bangladesh
md.baker@northsouth.edu

Mithila Sutradhar
Electrical and Computer Engineering
North South University
Dhaka, Bangladesh
mithila.sutradhar@northsouth.edu

Dr. Mohammad Abdul Qayum
Electrical and Computer Engineering
North South University
Dhaka, Bangladesh
mohammad.qayum@northsouth.edu

***Abstract*—The Heliomotors project introduces a cutting-edge ecosystem for multifunctional electric vehicles, focusing on sustainability, user engagement, and energy efficiency. This study develops Heliomotors, a solar-powered EV equipped with IoT devices that allow users to earn cryptocurrency through data annotation tasks. Users can also generate and sell surplus solar energy to the main grid and utilize a swappable battery system to minimize charging downtime. The vehicle's modular design supports customizable components, including an Air Conditioner alternative with a swamp cooler and other on-demand integrations. The methodologies include the development of foldable solar panels using origami robotics, the implementation of a blockchain-based reward system, and creation of an efficient battery swapping infrastructure. Key findings reveal that Heliomotors can significantly reduce carbon emissions, lower operational costs, and promote renewable energy use. The replaceable battery system notably reduces vehicle downtime, enhancing the practicality of EVs for various applications. This research underscores Heliomotors potential to revolutionize urban mobility by offering a scalable, eco-friendly alternative to traditional vehicles. By integrating advanced technologies and user-centric features, Heliomotors addresses current EV infrastructure limitations and sets the stage for future sustainable transportation advancements. Future research should also explore the potential for Solar-Enhanced Plug-in Hybrid Electric Vehicles (SE-PHEVs) that combine solar power with traditional fuel or grid-based charging. SE-PHEVs use integrated solar panels to replace traditional fuel and grid electricity, offering an eco-friendly and cost-effective transition toward fully EVs. In emergencies where solar energy or battery charge is insufficient, SE-PHEVs can switch to fuel as a backup, providing long-distance travel or areas with limited charging infrastructure. The study advocates for continued exploration of renewable energy integration and blockchain technology in automotive applications, highlighting the profound impact of interdisciplinary innovation on achieving global sustainability goals.**

Keywords—Solar-powered electric vehicles, origami robotics, Heliomotors, IoT devices in EVs, cryptocurrency rewards, renewable energy, swappable battery system, blockchain technology, sustainable transportation, urban mobility, EV infrastructure, eco-friendly vehicles, modular vehicle design

I. Introduction

Heliomotors introduce a groundbreaking multifunctional ecosystem for electric vehicles (EVs) that prioritizes sustainability, energy efficiency, and user engagement. Central to this initiative is the solar-powered Heliomotor vehicle, equipped with innovative foldable solar panels that harness renewable energy, reducing reliance on conventional charging. Users can generate and sell surplus energy back to the grid, fostering an energy-sharing community. The vehicle features a swappable battery system for quick replacements, minimizing downtime, and a customizable modular design that adapts to diverse needs. Enhanced by origami robotics for efficient solar capture and a blockchain-based reward system for transparent transactions, Heliomotors aims to significantly lower carbon emissions and operational costs. This project not only promotes a greener transportation ecosystem but also has the potential to transform urban mobility, offering a scalable and eco-friendly alternative to traditional vehicles. Additionally, the introduction of Solar-Enhanced Plug-in Hybrid Electric Vehicles (SE-PHEVs) further enriches this vision by combining hybrid technology with renewable solar power, providing consumers with a practical path toward fully electric vehicles.

The capacity of solar-powered electric vehicles (EVs) to lessen dependency on fossil fuels and encourage environmentally friendly mobility has drawn interest. Solar-powered electric vehicles were difficult to launch due to the inefficiency of solar panels and the energy requirements of the vehicles.However, the early progress in foldable solar panels has opened up new ways to use solar energy with EVs. They don't need to be charged often and allow cars to create energy while they are running. The EV world is changing due to new technologies like blockchain and the Internet of Things (IoT). IoT helps in better monitoring and collecting data in cars, which also increases user numbers and energy efficiency. Meanwhile, blockchain technology creates safe ways for users to share extra solar energy. The growth of modular vehicle designs allows for customization, making EVs more useful for different needs. These new ideas not only make electric vehicles (EVs) more sustainable, but they also create a flexible system that can change urban transport while reducing costs and carbon emissions.

The motivation of Heliomotors is to make a supportable and user-friendly ecosystem In EV.And integrate solar energy,IoT, and blockchain technology, this project goal is to reduce carbon emissions and encourage energy efficiency. Heliomotors visualize a future where EVs are more reachable , reducing dependency on non-renewable energy sources and promoting a cleaner environment. Moreover , this project seeks to improve user experience through modern technologies such as IoT for secure, highest accurate transactions, real-time data monitoring and blockchain. As a modular vehicle it allows for the greatest customization to provide a variety of needs. Heliomotors is mainly making EVs more practical and affordable.

Chowdhury et al. (2018) presented an optimal solar energy system to encourage electric vehicle charging at the University of Dhaka, targeting energy sustainability and pollution reduction in Bangladesh. The research employed the Hybrid Optimization of Multiple Energy Renewables (HOMER) program to estimate and optimize energy generation and consumption, producing roughly 13,792 kWh per year, with 21% allocated for electric vehicle charging. It contributes surplus energy to the national grid, reducing greenhouse gas emissions by 52,944 kg annually. This research shows the potential for integrating solar PV approaches to promote sustainable transportation.

Khan et al. reviewed solar-powered EV charging systems, exploring the environmental benefits of integrating solar PV technology into EV infrastructure. Their research emphasizes the technical aspects of charging station technologies, control systems, safety p*Energies*rotocols, and economic viability. It concludes that solar-powered EV charging is a promising, environmentally friendly solution for reducing dependence on fossil fuels.

Khoucha et al. proposed an interleaved boost converter for solar EVs, enhancing efficiency and reducing filter requirements. Their system incorporates a Maximum Power Point Tracking (MPPT) controller, which optimizes solar energy extraction. MATLAB-Simulink simulations confirmed the converter's effectiveness in boosting system efficiency with minimal power loss. This work emphasizes the importance of optimizing power electronics for solar vehicle applications.

Oosthuizen et al. (2019) optimized energy usage in solar EVs during the Sasol Solar Challenge 2018 by integrating optimization algorithms with weather forecasting data. The research demonstrated how speed control algorithms can improve energy efficiency and maximize distance traveled under varying weather conditions. This study highlights the importance of formal strategies to optimize EV energy consumption and performance in competitive environments.

Paterson et al. (2016) documented the design and development of the Sunswift eVe solar-electric hybrid car at the University of New South Wales. Equipped with a solar array and a 16 kWh battery, this vehicle achieved significant milestones, including winning the World Solar Challenge. The project underscores the potential of solar-electric hybrid vehicles to reduce carbon emissions and advance sustainable transportation.

Ahmad, Khalid, and Panigrahi introduced an optimal placement approach for solar-powered EV charging stations within a distribution network. Their system improved voltage profiles, minimized power losses, and reduced costs. The study utilized a stochastic approach for predicting EV load demand, paired with a neural network to estimate solar power, demonstrating the necessity of proper infrastructure to support EV expansion.

Shariff et al. (2019) presented a solar-powered EV charging station designed for Aligarh Muslim University, combining solar PV, grid power, and battery storage. The station supplies a 5-6 kW daily charging load, addressing the critical issues of fossil fuel depletion and global warming by promoting solar-based transportation solutions.

Fathabadi (2017) proposed a grid-connected solar-powered EV charging station featuring Vehicle-to-Grid (V2G) technology. His research highlighted the benefits of using an advanced MPPT technique to improve energy efficiency and support grid stability during peak loads. This study provides a viable model for future solar-based EV infrastructure.

Mohammadi's research on solar-powered EVs explored the integration of solar energy with conventional plug-in power, reducing greenhouse gas emissions. The study emphasizes hybrid architectures that maximize fuel savings and increase energy efficiency, showing the promise of dual-mode power systems for sustainable transportation.

Gupta et al. examined solar-based EV charging stations in Delhi, India, highlighting their potential to reduce reliance on fossil fuels, lower CO2 emissions, and offer long-term economic savings. The paper proposes deploying charging stations every 25 kilometers to support EV adoption, presenting solar-based infrastructure as a solution for environmental and financial challenges.

Zhang et al. focused on developing Solar Electric Vehicles (SEVs) and Solar Electric Buses (SEBs) with dual-mode power systems incorporating PV panels and batteries. The Kundi model demonstrated a 35% increase in driving range due to solar integration, reducing greenhouse gas emissions and dependence on fossil fuels.

Ye et al. evaluated the environmental and economic benefits of solar-powered EV charging stations, offering detailed analyses of their feasibility. The study bridges gaps in earlier research by providing comprehensive insights into the advantages of solar EV infrastructure for mitigating carbon emissions and operational costs.

Deshmukh & Pearce assessed the viability of integrating solar PV awnings into retail parking lots for EV charging. Their findings show significant reductions in carbon emissions and economic feasibility, supporting the integration of renewable energy into daily infrastructure for sustainable transportation.

Mouli et al. proposed solar-powered charging stations for workplace environments. Their research focused on reducing grid dependency by optimizing workplace energy production and consumption patterns. This study highlights the importance of solar energy integration in commercial spaces to support sustainable EV charging.

Bhatti et al. provided an overview of advancements in solar PV technology and its application to EV infrastructure. The study analyzed the environmental and economic benefits of solar-powered EV charging, emphasizing its potential to reduce carbon emissions and promote sustainable energy practices.

Khare & Bunglowala explored various design approaches for solar-powered EVs, incorporating MPPT systems, lithium-ion batteries, and lightweight materials to enhance efficiency. Their research demonstrated that solar EVs could significantly extend driving range while reducing energy consumption, offering a sustainable solution for the future of transportation.

Teshima et al. developed strategies for maximizing energy efficiency in solar electric vehicles (SEVs) through route planning, adaptive speed control, and regenerative braking systems. The study emphasizes the importance of integrated driving strategies for enhancing SEV performance.

Kostopoulos et al. quantified the contribution of solar energy to EVs, showing that solar panels can supplement energy requirements effectively under favorable conditions. Their research provides empirical data to optimize solar panel placement and maximize sustainability in electric vehicle systems.

Mumin Cebe, Enes Erdin, Kemal Akkaya, Hidayet Aksu, and Selcuk Uluagac propose that Block4Forensic is a blockchain-based framework to remedy the shortcomings of conventional accident investigations. They showed a high spot for how existing tools, Event Data Recorders (EDR), and Onboard Diagnostics (OBD) must be improved due to data storage limitations and fiddling risks. It basically ensures secure, tamper-proof collection and storage while securing privacy for all involved teams. By administering an authorized blockchain with fragmented ledgers, authors try to invent a system that minimizes storage operating costs and makes a good idea for related vehicles. This design assures trustworthy data sharing among stakeholders like drivers, insurance companies, and law enforcement without reliance on a single trusted party. However, the concept of 'robust' real-world validation is needed to evaluate flexibility and performance.

Mohamed Amine Ferrag, Makhlouf Derdour, Mithun Mukherjee, Abdelouahid Derhab, Leandros Maglaras, and Helge Janicke proposed that a broad survey investigate the use of blockchain in the Internet of Things (IoT). They classify existing security risks in IoT, such as identity-centric and control-orientate attacks, and demonstrate how blockchain can reduce these risks. Through a comprehensive classification of recent methods, the performance, complexity, and limitations of various blockchain protocols that authors compared that used in IoT. One of the advantages of the paper is its focus on blockchain's capability to provide decentralized, secure proposals for IoT applications such as healthcare, energy, and smart towns. However, the authors highlight that current blockchain applications struggle with energy inefficacy, scalability, and storage limitations. They suggest that future research should focus on eco-friendly consensus methods and improved defense against threats.

Muhammad Baqer Mollah, Jun Zhao, and Dusit Niyato proposed exploring the application of blockchain technology to the Internet of Vehicles (IoV) as a solution to improve safety,clarity, and productivity in Intelligent Transportation Systems (ITS). They emphasise how blockchain can provide decentralised identity management, trusted communication (end-to-end encryption) between vehicles, and security against unauthorised access or data transformation. The authors highlight the possibility of blockchain to transform IoV networks, but they also highlight obstacles such as resource restrictions in vehicular systems and the need for thin blockchain solutions. The paper classifies research gaps in flexibility and productivity that require further analysis , suggesting that future research should focus on developing blockchain systems adapted specifically to IoV's resource-constrained environments.

A blo Hizal (2023) proposed a blockchain-based reputation management system designed for the Internet of Vehicles (IoVT), solving important challenges, including security, faith, and clarity in vehicular networks. This article highlights a healing method based on cryptocurrencies that empower cars to get standing points back after receiving fines. However,proposing a novel strategy of monitoring vehicle behavior, this decentralised system also ensures protection , flexibility , and fairness. By saving reputation information on blockchain, it does away with the need for unfied systems and ensures data integrity and cyberattack resistance . The technology provides police agencies with detailed records to support decisions made in real time by mechanizing vehicle brand management through the use of smart contracts. Hizal's method offers the strongest match approach to intensifying vehicular trust management and traffic security.

Peng et al. (2020) proposed the technology's capabilities to deconcentrate vehicular networks and solve problems such as high latent period and few conveying resources. The study documents the main benefits of blockchain technology, like its distribution, traceability, and fault acceptance, which make it the best way for data management in self-propelled systems. In addition, Peng et al. also focused on technical issues, including how vehicle motion raises problems in different situations and the requirement for a thin consensus way that works well in dynamic contexts like those seen in cars. This investigation offers an observant look at how blockchain technology is progressively being used to enable secure, effective, and transparent vehicle IoT systems.

Dorokhova et al. (2021) propose a novel framework that leverages blockchain technology to address the limitations of traditional EV charging management systems. The authors argue that blockchain's inherent security, transparency, and decentralization make it an ideal solution for managing secure energy trading and payment processing in EV charging scenarios. The paper outlines the design and implementation of the framework, including a web interface for charging station owners, a mobile application for EV users, and the use of smart contracts to govern the charging process. While recognizing certain limitations, the authors suggest future research avenues, such as exploring alternative consensus mechanisms and integrating renewable energy sources into the framework.

Jabbar et al. (2021) introduce a Blockchain-based Internet of Things (IoT) system aimed at enhancing security and improving data transmission accuracy in Vehicle-to-Everything (V2X) communication. The paper presents the Decentralized IoT Solution for Vehicle communication (DISV), which uses blockchain technology to create a secure communication channel and a decentralized cloud computing platform for V2X interactions. A model-based testing framework is developed to validate the system, with an optimization phase for tester placement inspired by fog computing principles. While the study addresses significant challenges in Internet of Vehicles (IoV) security, further details on the implementation, performance evaluation, and comparative analysis with existing solutions are needed to enhance its impact.

Bauer et al. (2018) explore how businesses can leverage blockchain technology to create value within the automotive ecosystem. Using interviews and workshops with industry experts and blockchain specialists, the authors identify three key areas where blockchain can drive value: distributed product innovation, controlled customer intimacy, and shared operational efficiency. While the study provides early evidence of these benefits, it also highlights several challenges, such as managing stakeholder interests, potential competition, and navigating legal and regulatory frameworks. This research offers valuable insights and guidelines for businesses looking to adopt blockchain technology in the automotive sector.

Yaqub et al. (2021) propose an innovative system to address the billing challenges faced by roaming electric vehicles using different charging providers. The system integrates blockchain technology to record charging transactions, ensuring transparency and security, while AI is used to predict charging demand and optimize costs based on factors such as time and location. The system aims to simplify billing for roaming EV users, offering a unified bill across different providers and incorporating potential loyalty programs and discounts. This solution addresses a critical pain point in EV billing and enhances user convenience.

Biswas and Wang (2023) provide a comprehensive review of how IoT, edge intelligence, 5G, and blockchain technologies can be integrated to support the development and deployment of autonomous vehicles (AVs). The paper highlights that these technologies are crucial for addressing the safety, security, and reliability challenges associated with AVs. In addition to exploring the state-of-the-art in each technology, the authors discuss the necessary advancements for seamless integration and outline future research directions, particularly in terms of enhancing AV safety and performance.

Jeong et al. (2020) propose a blockchain-based marketplace platform for secure and efficient vehicle data sharing and trading. The paper addresses the growing need for data security in the context of connected and autonomous vehicles, focusing on ensuring data confidentiality, integrity, and privacy. By using blockchain to store metadata on-chain and encrypting raw data off-chain, the proposed system strikes a balance between transparency and data protection. The use of decentralized access control mechanisms allows vehicle owners to manage data transactions securely. This approach provides a robust framework for managing vehicle data in a connected ecosystem.

Zhao et al. (2021) present a novel authentication scheme for vehicles in the Internet of Vehicles (IoV), aimed at balancing security and efficiency. The proposed scheme utilizes blockchain technology, threshold-shared multi-signatures, and identity federations to achieve secure cross-domain authentication. The authors implement the scheme using smart contracts and demonstrate that it achieves a lower computational overhead compared to existing solutions. This efficient authentication framework holds promise for enhancing the security and scalability of IoV networks.

II. Key Challenges & Opportunities

A. *Technical Challenges*

Solar-powered electric vehicles (EVs), like those proposed by the Heliomotors project, face several technical hurdles that must be overcome to achieve widespread adoption. One of the primary challenges lies in the efficiency of foldable solar panels. Although origami robotics enable foldable designs that maximize energy capture in limited spaces, these panels must be durable, lightweight, and highly efficient in energy conversion. These panels need to withstand the physical stress of repeated folding and unfolding while maintaining high energy conversion efficiency. Ensuring consistent energy output under varying weather conditions and optimizing the panels for urban settings (where direct sunlight may not always be available) remain significant technical obstacles.

Another key challenge involves battery technology and management. Integrating cutting-edge technologies in Heliomotors, particularly lithium-ion batteries, presents multiple technical challenges. By grouping 3/4 cells as one, the battery design enhances capacity while maintaining a swappable system. While swappable battery systems offer a solution to long charging times, there are logistical and technological issues to address. For instance, ensuring compatibility across different vehicle models and designing an infrastructure for fast, standardized battery swaps requires collaboration across industries. There's also the need for fast charging technologies that ensure minimal waiting times during battery swaps, without compromising the lifespan of the batteries. Additionally, battery degradation over time poses challenges regarding reliability, safety, and environmental impact.

The integration of blockchain technology for cryptocurrency rewards and energy sharing also presents challenges. The IoT and blockchain reward system, which issues tokens to users as part of their vehicle's operation, adds another layer of complexity. These tokens can later be exchanged for points, but blockchain systems often face challenges related to scalability and security. As the number of transactions related to energy sharing, rewards, and other decentralized processes grows, maintaining transaction speed, cost efficiency, and user privacy will be critical. Moreover, energy transactions on a distributed network must be secure against cyber threats, and the blockchain infrastructure itself must be energy efficient to avoid countering the environmental benefits of solar-powered EVs.

B. *Adoption Barriers*

Beyond the technical challenges, there are considerable barriers to adoption that must be addressed for solar-powered EVs to become mainstream. The high initial cost of solar-powered EVs, driven by the costs of solar panels, advanced batteries, and IoT integration, can deter potential buyers, especially in developing markets. Government incentives, tax breaks, and subsidies will play a crucial role in making these vehicles more accessible.

Additionally, the lack of charging and battery-swapping infrastructure presents a major barrier. While lithium-ion batteries offer greater efficiency and solar panels reduce dependency on grid power, the cost of producing and installing these components can deter early adopters. Also, traditional EVs are supported by a growing network of charging stations, the infrastructure for solar-powered EVs (including solar charging stations and battery-swapping facilities) is not yet fully developed. Governments, private stakeholders, and automotive companies need to invest heavily in infrastructure development to support the growth of solar-powered EVs.

Consumer acceptance is another challenge. Many consumers remain unfamiliar with the concept of solar-powered EVs or are skeptical of their reliability, particularly when it comes to energy generation in cloudy or urban environments. Overcoming this perception will require not only technological advancement but also widespread education and marketing efforts to build consumer confidence in the technology to maintain consistent performance even in less-than-optimal sunlight conditions.

C. *Opportunities for Innovation*

Despite the challenges, there are significant opportunities for innovation within the solar-powered EV ecosystem. Lithium-ion battery technology, while already advanced, continues to evolve. The integration of multiple cells as one offers new possibilities for increasing energy density while keeping the battery swappable. Advancements in solar panel technology, such as more efficient photovoltaic cells and materials that can harness energy even in low-light conditions, are ongoing and could greatly enhance the efficiency of vehicles like Heliomotors. Further research into flexible, lightweight, and durable materials will increase the viability of foldable solar panels, extending the range and utility of solar-powered EVs.

Origami-inspired foldable solar panels present exciting opportunities for urban mobility, especially as cities seek to reduce carbon emissions and energy consumption. New advancements in materials science, such as the development of lightweight, durable, and highly efficient photovoltaic materials, could further enhance the efficiency of these solar panels.

The development of next-generation batteries presents another major opportunity. Innovations such as solid-state batteries, which offer greater energy density, longer lifespans, and improved safety over traditional lithium-ion batteries, could revolutionize both the swappable battery system and the overall performance of solar-powered EVs.

The blockchain-based reward system, while still in its infancy in the automotive sector, offers the potential for new economic models that could incentivize the adoption of solar-powered EVs. By enabling users to earn tokens for surplus energy contributions, or participation in data annotation tasks, the system introduces new economic models that go beyond conventional ownership. Additionally, the ability to convert tokens into points for practical uses or even cash equivalents can turn these vehicles into platforms for user interaction, fostering a community-driven ecosystem around sustainability.

The introduction of Solar-Enhanced Plug-in Hybrid Electric Vehicles (SE-PHEVs) marks a significant innovation. SE-PHEVs blend solar power with traditional fuel and grid-based charging, offering a flexible, efficient solution for users not yet ready to fully transition to electric vehicles. This hybrid model could accelerate adoption by providing an intermediate technology that reduces reliance on fossil fuels while enhancing overall energy efficiency.

Finally, the modular design of vehicles like Heliomotors offers significant opportunities for customization and user-driven innovation. By allowing users to swap out components based on their needs (e.g., choosing a swamp cooler over a traditional AC), manufacturers can cater to diverse market demands, enhance the lifecycle of vehicles, and reduce maintenance costs.

III. Discussion & Analysis

A. *Synthesis of Findings*

The integration of solar power, IoT technology, blockchain, and swappable battery systems represents an interdisciplinary approach that could significantly impact the future of electric vehicles. Studies suggest that the ongoing advancements in these fields have the potential to overcome many of the current limitations in energy generation, storage, and vehicle customization.

Heliomotors leverages origami-based foldable solar panels to maximize energy capture. The ability to deploy these panels in limited urban spaces could address the common issue of insufficient solar exposure in densely populated areas. The literature also highlights the potential of IoT to create a more connected and efficient transportation ecosystem by gathering data on energy consumption, driving behavior, and vehicle maintenance.

The concept of battery swapping has been explored in various EV studies, and the implementation of a standardized, swappable lithium-ion battery system can significantly reduce downtime, making the ownership experience more convenient. Further analysis of existing battery-swapping models, particularly in China's EV market, supports the potential for widespread implementation, provided the necessary infrastructure is built.

IoT and Blockchain-based reward systems, while relatively new in automotive applications, offer promising avenues for building a community-driven energy-sharing economy. The reward system based on tokens allows for a user-driven economy, where individuals can earn points for their engagement with the vehicle and its ecosystem. This feature represents a blend of technological and economic innovation and aims to create an ecosystem where users not only operate their vehicles but also contribute to a decentralized energy grid.

B. *Interdisciplinary Integration*

The Heliomotors project is unique in its comprehensive integration of multiple technologies. Solar energy generation is not treated in isolation; it is combined with blockchain-based rewards to promote user engagement, and IoT devices to enhance data-driven decision-making. This interdisciplinary approach represents a new paradigm in electric vehicle design, where sustainability and user interaction are at the forefront.

The addition of SE-PHEVs further expands this interdisciplinary integration. By blending the flexibility of hybrid technology with the benefits of renewable solar energy, SE-PHEVs offer a more gradual transition for consumers wary of fully electric vehicles. This hybrid solution provides an intermediate step, reducing fuel dependency while still allowing for long-range travel or use in areas where solar efficiency may be lower.

By creating a networked ecosystem where energy generation, consumption, and user behavior are all interconnected, Heliomotors presents a model for next-generation transportation systems. The combination of solar power and a modular, customizable vehicle architecture also provides flexibility and adaptability, ensuring that Heliomotors vehicles can meet the varying needs of different urban environments.

C. *Impact on Sustainability*

Heliomotors and SE-PHEVs have the potential to significantly impact urban sustainability by reducing carbon emissions, decreasing reliance on fossil fuels, and promoting renewable energy usage. The surplus solar energy selling feature can create a circular economy, where energy is generated, consumed, and redistributed locally. This approach reduces the strain on centralized power grids and promotes energy independence at the individual and community levels.

Moreover, by offering battery-swapping technology, Heliomotors reduce the downtime associated with traditional EV charging, ensuring that users can operate their vehicles with minimal disruption. This improvement in convenience is expected to make solar-powered EVs more appealing to the broader market, accelerating the shift toward greener urban mobility.

IV. Future Directions

A. *Technology Development*

The future development of solar-powered EVs hinges on advancing the underlying technologies that drive energy generation, storage, and user engagement. Foldable Solar panel technology needs to continue evolving toward higher energy efficiency and flexibility. Materials science advancements will play a crucial role in developing lightweight, foldable panels that can maximize energy capture even in challenging urban environments.

Battery technology also requires further innovation. The development of lithium-ion batteries and other next-generation energy storage solutions could enhance the swappable battery system, improving vehicle range and reducing environmental impact. Research into sustainable battery recycling and disposal processes will also be critical to minimize the environmental footprint of large-scale battery use.

B. *Policy and Infrastructure*

For solar-powered EVs to become a practical option for everyday users, the success of Heliomotors will depend on significant investment in supportive infrastructure, including solar charging stations, battery-swapping facilities, and decentralized energy grids that can support energy-sharing models. Policymakers need to create incentives that encourage consumers to adopt solar-powered EVs, such as tax credits, rebates, and subsidies for installing home-based solar charging systems.

Additionally, policies must be in place to standardize battery-swapping infrastructure and support the deployment of SE-PHEVs as a transitional technology. Establishing universal standards for battery size, capacity, and charging protocols would facilitate widespread adoption and make it easier for consumers to access swapping services, also encourage the integration of solar panels in hybrid vehicles, combined with incentives for reducing fuel consumption, will play a critical role in advancing hybrid adoption.

C. User-Centric Design

As technology evolves, the design of Heliomotors and SE-PHEVs must remain user-centric, allowing for greater customization and personalization. Modular designs, which allow users to upgrade components such as batteries or cooling systems, will ensure that vehicles can adapt to changing user needs, extending their operational lifespan and a more personalized experience. Future research should explore how to enhance the user interface of vehicles, making it easier to track energy consumption, battery health, and reward earnings from activities such as data annotation.

D. Research on Solar-Enhanced Hybrid Electric Vehicles (SE-PHEVs)

The primary focus of Heliomotors is on developing fully solar-powered electric vehicles (EVs) that utilize solar energy as their main power source, reducing reliance on conventional charging methods. However, future research will focus on the development of Solar-Enhanced Plug-in Hybrid Electric Vehicles (SE-PHEVs), which offer an innovative solution for instances where solar or battery energy is insufficient. The goal is not to maximize fuel usage, but rather to reserve it strictly for emergency situations or long-distance travel in areas with limited solar or charging resources.

In this approach, SE-PHEVs will use integrated solar panels to generate the majority of the energy required for propulsion, relying on fuel as a backup only when solar power or battery reserves are depleted. This ensures that solar energy remains the primary source of power, supporting a more sustainable and cost-effective mobility solution while offering the flexibility of a hybrid system when necessary. Fuel would act as an emergency alternative, providing peace of mind to drivers on extended journeys or in regions with unpredictable weather conditions.

SE-PHEVs represent a seamless transition from traditional fuel-powered vehicles to a cleaner, more sustainable future, with solar energy taking precedence. In contrast to conventional hybrids, where both fuel and electricity are used regularly, SE-PHEVs under the Heliomotors vision will prioritize renewable solar energy, reducing carbon emissions and operational costs while keeping fuel consumption to an absolute minimum. This approach also makes SE-PHEVs particularly appealing to regions where charging infrastructure is limited or unreliable, ensuring uninterrupted travel without significantly increasing the vehicle's environmental footprint.

The development of SE-PHEVs will provide a crucial bridge toward fully solar-powered transportation, offering consumers an eco-friendly vehicle option that adapts to a variety of driving conditions. By using solar energy as the primary power source and fuel only in specific circumstances, these vehicles align with Heliomotors mission to revolutionize the EV market with sustainable, energy-efficient alternatives that prioritize renewable resources.

V. Conclusion

The Heliomotors project represents a pioneering step towards creating a comprehensive ecosystem for multifunctional solar-powered electric vehicles (EVs). By leveraging innovative technologies such as foldable solar panels using origami robotics, IoT devices, blockchain-based reward systems, and a swappable battery infrastructure, this project provides a holistic solution that prioritizes sustainability, user engagement, and energy efficiency. The primary contribution of Heliomotors lies in its focus on solar energy as the main power source for EVs, significantly reducing dependency on conventional grid-based charging and fossil fuels. The swappable battery system minimizes vehicle downtime, enhancing operational efficiency and making EVs more practical for daily use.

One of the key innovations of the project is the introduction of a blockchain-based reward system that incentivizes users to generate surplus solar energy and engage in data annotation tasks, creating new economic models within the energy-sharing ecosystem. This system fosters decentralized, user-driven participation, where surplus energy can be sold back to the grid, thus contributing to energy independence and the wider adoption of renewable resources.

Furthermore, the Heliomotors modular design offers customization options that allow users to tailor the vehicle's components to their specific needs, such as an air conditioning alternative using a swamp cooler. This flexibility, combined with the vehicle's energy-efficient design, reduces both operational costs and carbon emissions, making Heliomotors a practical solution for a variety of environments.

Looking ahead, the development of Solar-Enhanced Plug-in Hybrid Electric Vehicles (SE-PHEVs) marks an important future direction. SE-PHEVs would use solar energy as the primary power source, with traditional fuel acting only as a backup in cases of insufficient solar energy or battery charge. This approach offers an ideal transition for consumers moving from conventional vehicles to renewable energy solutions. By integrating solar power and traditional fuel, SE-PHEVs ensure long-distance travel and continuous operation even in areas with limited charging infrastructure or adverse weather conditions, further expanding the reach and appeal of solar-powered vehicles.

The challenges of energy storage, panel efficiency, and infrastructure development still require further research. Improving the efficiency of solar panels, optimizing the swappable battery system, and advancing battery management technologies are key areas that will define the future viability of solar-powered EVs. Additionally, the scalability of blockchain-based reward systems needs to be refined to handle increased energy-sharing transactions while maintaining security and speed.

Heliomotors set the stage for a transformative shift in the EV market, demonstrating that interdisciplinary innovations can address pressing issues such as carbon emissions, energy efficiency, and urban mobility. By combining solar energy, IoT, blockchain, and modular vehicle design, Heliomotors not only contributes to the current EV landscape but also offers a scalable, eco-friendly solution for the future of transportation. The project highlights the importance of continued research into renewable energy, sustainable infrastructure, and hybrid vehicle models, marking an essential step toward achieving global sustainability goals.

References

[1] G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*

[2]

[3]

[4] K. Elissa, “Title of paper if known,” unpublished.

[5] R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.