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Transforming Conventional Vehicles into Electric: A Comprehensive Review of Conversion Technologies, Challenges, Performance Enhancements, and Future Prospects

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Abstract: The transition from internal combustion engine (ICE) vehicles to electric vehicles (EVs) is a critical step toward reducing greenhouse gas emissions and promoting sustainable transportation. While purchasing new EVs remains a primary solution, converting existing ICE vehicles into EVs presents a cost-effective and environmentally beneficial alternative. This paper provides a comprehensive review of the EV conversion process, including the key technical components such as electric motors, battery packs, and power management systems. It explores the different types of conversions, ranging from full powertrains replacements to partial modifications, and examines the associated challenges, including battery range limitations, vehicle compatibility, and economic feasibility. Furthermore, the study evaluates recent advancements in conversion technologies, such as improvements in battery energy density, fast-charging infrastructure, and the integration of renewable energy sources. By analyzing the latest research findings, the paper compares the performance, efficiency, and emissions reductions of converted EVs with factory-manufactured electric models. Additionally, it identifies critical research gaps, including the need for standardized conversion regulations, comprehensive lifecycle assessments, and strategies to enhance consumer adoption. The findings suggest that EV conversions have significant potential to accelerate the electrification of transportation, particularly in regions where new EV adoption is limited due to economic constraints. However, achieving large-scale implementation requires further advancements in technology, cost reduction strategies, and supportive government policies. This review concludes with recommendations for improving conversion efficiency, reducing financial barriers, and fostering a regulatory framework that facilitates the widespread adoption of EV conversion as a viable sustainability solution.

Keywords: Electric vehicles (EVs); internal combustion engine (ICE); Engine emissions; Cost-benefit analysis (CBA); greenhouse gas (GHG) emissions

1. Introduction

The global transportation sector is undergoing a significant transformation as governments, industries, and consumers seek sustainable alternatives to traditional fossil fuel-powered vehicles [1-6]. Internal combustion engine (ICE) vehicles, which have dominated road transportation for over a century, are now recognized as major contributors to air pollution, greenhouse gas emissions, and climate change [7-13]. In response, electric vehicles (EVs) have emerged as a cleaner, more energy-efficient alternative that aligns with global sustainability goals [14-20]. However, the widespread adoption of new EVs is hindered by several factors, including high initial costs, the resource-intensive manufacturing of batteries, and the gradual phasing out of existing vehicle fleets. Given these challenges, converting ICE vehicles into EVs has gained increasing attention as a practical and economically viable approach to accelerating the transition toward sustainable transportation.

EV conversion involves replacing the traditional fuel-dependent powertrains of an ICE vehicle with an electric motor, battery system, and power management electronics, effectively transforming it into a fully electric vehicle [21-25]. This approach offers several advantages, including a significant reduction in carbon emissions, lower operational and maintenance costs, and the extended usability of existing vehicles, which minimizes waste and resource depletion. Additionally, vehicle conversion can be an attractive option for classic car enthusiasts, commercial fleet operators, and consumers in regions where new EVs remain financially inaccessible [26-33]. Despite these benefits, the process of converting conventional vehicles into EVs presents multiple challenges, such as technical compatibility issues, energy storage limitations, high initial conversion costs, and the lack of standardized regulatory frameworks [34-40]. Addressing these obstacles is crucial to ensuring the feasibility, efficiency, and large-scale implementation of EV conversions.

This paper provides an in-depth analysis of EV conversion technologies, highlighting the key components involved, such as electric motors, battery systems, and power electronics. It categorizes different types of conversions, ranging from full replacements of ICE powertrains to partial modifications that integrate hybrid electric solutions. Furthermore, the study examines the latest advancements in battery technology, electric drivetrains, and charging infrastructure, which have significantly improved the efficiency and performance of converted EVs. In addition, the paper evaluates recent research findings comparing the energy consumption, emissions reductions, and long-term cost benefits of converted EVs versus factory-produced electric models. Moreover, this review identifies critical research gaps and areas for further development, including the need for standardized conversion guidelines, comprehensive lifecycle assessments, and policy incentives to support large-scale adoption. By addressing these gaps, governments and industry stakeholders can help facilitate the widespread adoption of EV conversions as a mainstream solution for reducing transportation-related carbon emissions.

Ultimately, this study aims to contribute to the growing body of research on sustainable transportation solutions by providing insights into the challenges, innovations, and future prospects of EV conversions. By leveraging emerging technologies, regulatory support, and economic incentives, EV conversions can play a pivotal role in the global transition toward a cleaner, more energy-efficient mobility landscape

2. Overview of Internal Combustion Engine (ICE) to Electric Vehicle (EV) Conversions

A. Definition and Importance of EV Conversions:

Electric vehicle (EV) conversions involve transforming conventional internal combustion engine (ICE) vehicles into electric vehicles by replacing the engine with an electric motor and battery system. This process is gaining traction as a sustainable transportation solution, offering environmental and economic benefits. EV conversions reduce greenhouse gas emissions and air pollution, contributing to a cleaner environment. They also lower operational costs due to reduced maintenance needs and the use of electricity instead of fossil fuels. The conversion process typically includes the integration of components such as a brushless DC motor, motor controller, and battery pack, which are essential for the vehicle's propulsion and efficiency[41].

The conversion of internal combustion engine (ICE) vehicles to electric vehicles (EVs) presents a promising pathway toward achieving both environmental sustainability and economic efficiency. One of the key environmental benefits of EV conversions is the significant reduction in reliance on fossil fuels. This shift not only conserves non-renewable energy resources but also leads to a marked decrease in greenhouse gas emissions and air pollutants, contributing to improved air quality and climate change mitigation efforts.

Economically, EV conversions offer considerable advantages over traditional ICE vehicles. Due to the simplicity of electric drivetrains, converted EVs generally require less frequent and less costly maintenance. Additionally, their operational costs such as energy consumption are notably lower. These savings translate into tangible financial returns over time. In fact, the initial investment in EV conversion can be recovered in as little as three years, making it a financially sound option. This is particularly beneficial for commercial entities, such as delivery and logistics companies, that operate large vehicle fleets and prioritize long-term cost reduction[42].The technical process of converting an internal combustion engine (ICE) vehicle to an electric vehicle (EV) involves several critical steps and components. Central to this conversion is the replacement of the ICE with an electric motor, which commonly a brushless DC (BLDC) motor renowned for its high efficiency, durability, and reliable performance under varying load conditions. In addition to the electric motor, several essential components play key roles in ensuring the effective operation of the converted EV. The motor controller is one such component; it regulates and optimizes the delivery of electrical power from the battery to the motor, enabling smooth acceleration and efficient energy use. Another vital element is the battery pack, which serves as the main energy reservoir, storing electrical energy and supplying it as needed to propel the vehicle.

Furthermore, power electronics converters are indispensable in the conversion system. These devices manage the interface between the EV and external power sources, such as the electrical grid or charging stations. They ensure efficient bidirectional energy flow, enable proper voltage and current control, and maintain optimal motor performance during operation. Together, these components form the backbone of the EV conversion process, ensuring the system operates safely, reliably, and efficiently. Converting internal combustion engine (ICE) vehicles to electric vehicles (EVs) offers significant environmental and economic benefits. Environmentally, it reduces reliance on fossil fuels, decreasing greenhouse gas emissions and air pollution, thus contributing to climate change mitigation. Economically, converted EVs are more cost-effective, requiring less maintenance and having lower operational costs compared to ICE vehicles, with a payback period for conversion costs often as short as three years. This makes EV conversions financially viable, particularly for businesses in the delivery sector.

The conversion process involves replacing the ICE with a brushless DC motor, known for its efficiency and reliability. Key components include the motor controller, which optimizes power delivery, and the battery pack, which stores energy for propulsion. Power electronics converters are crucial for ensuring efficient energy transfer between the EV and charging infrastructure[43].However, EV conversions present challenges. Adapting the vehicle’s chassis to fit the new electric drivetrains and integrating an effective charging system are significant technical hurdles. Additionally, a well-developed charging infrastructure is essential for the widespread adoption of converted EVs, particularly in urban areas. Overcoming these challenges is key to maximizing the potential of EV conversions as a sustainable transportation solution.

B. Key Components of EV Conversion

The conversion of conventional vehicles to electric vehicles (EVs) involves several critical components that ensure functionality, efficiency, and safety. The primary elements include the electric motor, motor controller, battery pack, and power conversion systems. Each component plays a vital role in the overall performance of the converted vehicle, contributing to its operational efficiency and environmental benefits.

Electric vehicle (EV) conversion involves the integration of several key components that collectively enable the transformation of an internal combustion engine (ICE) vehicle into a fully electric one. At the core of this process, the electric motor is commonly a Brushless DC (BLDC) motor chosen for its high efficiency, reliability, and compact design, which facilitates installation in existing vehicle structures. Complementing the motor is the motor controller, a critical unit responsible for regulating the power delivered to the motor. It ensures optimal performance, energy efficiency, and smooth vehicle operation under different driving conditions. Another essential component is the battery pack. A carefully engineered battery system is vital for supplying the energy required for propulsion. Its specifications, including capacity and voltage, vary depending on the vehicle's range needs and operational load. Supporting these core elements are power conversion systems, particularly DC-DC converters. These systems play a crucial role in managing voltage levels across various subsystems, thereby enhancing charging efficiency and overall performance of the converted vehicle[44].Despite the numerous advantages EV conversions offer such as lower emissions and reduced maintenance costs they also introduce specific technical challenges. Among these are the demand for adequate and accessible charging infrastructure, as well as the risk of electromagnetic interference, which can affect vehicle electronics and performance. Addressing these issues is essential for ensuring the reliability and scalability of EV conversion projects.

C. Comparison Between Factory-Made EVs and Converted EVs

Factory-made electric vehicles (EVs) and converted EVs each offer unique advantages and challenges. Factory made EVs are designed from the ground up to be electric, often featuring optimized aerodynamics, integrated battery systems, and advanced technology. In contrast, converted EVs involve retrofitting existing internal combustion engine (ICE) vehicles with electric motors and batteries, which can be a cost-effective and sustainable alternative, especially in regions with limited access to new EVs. The following sections explore the key differences between these two approaches.

Factory-manufactured electric vehicles (EVs) are purpose-built with all components specifically engineered for electric propulsion. This integrated design approach ensures optimal performance, higher efficiency, and extended driving range, as every part of the vehicle from the chassis to the battery system is optimized for electric operation.

In contrast, converted EVs, while offering notable environmental and economic benefits, may encounter certain performance limitations. These limitations often stem from the original design of the internal combustion engine (ICE) vehicle, which was not intended for electric use. Challenges such as increased weight, suboptimal weight distribution, and less efficient aerodynamics can reduce the overall efficiency and range of the converted vehicle. Nevertheless, EV conversions still provide substantial reductions in emissions and fuel consumption, making them a valuable transitional solution toward sustainable transportation[45].

Factory-manufactured electric vehicles (EVs) are often associated with high initial costs, which can limit their adoption, especially in developing countries. In these regions, the lack of mature charging infrastructure and limited government incentives further intensify the financial burden, making factory EVs less accessible to the general population. In contrast, converting existing internal combustion engine (ICE) vehicles into EVs presents a more affordable alternative. This cost-effective approach enables a broader audience to access EV technology without the need to purchase new vehicles [46-48]. It is particularly advantageous in markets where the price of factory-made EVs is prohibitive, allowing for a more inclusive and practical transition toward sustainable transportation[49].

Both factory-manufactured and converted electric vehicles (EVs) play a crucial role in reducing greenhouse gas emissions and minimizing air pollution, contributing significantly to global environmental goals. While factory-made EVs are designed with efficiency in mind, vehicle conversions offer an additional sustainability advantage. By extending the operational life of existing internal combustion engine (ICE) vehicles, conversions help reduces the demand for new vehicle production. This, in turn, lowers the environmental footprint associated with raw material extraction, manufacturing processes, and vehicle disposal. Factory-made EVs often feature advanced technology, such as regenerative braking and sophisticated battery management systems, which may not be present in converted vehicles. On the other hand, converted EVs can incorporate modern components like ultracapacitors to enhance performance, as demonstrated in studies where such additions improved acceleration and battery life[50].Factory-made EVs offer a seamless and technologically advanced experience, converted EVs provide a practical and sustainable alternative, especially in regions with economic or infrastructural constraints. The choice between the two depends on factors such as cost, availability, and specific transportation needs.

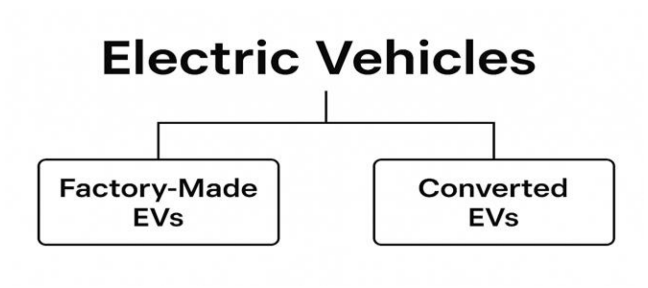

Fig1: Electric vehicle types

3. Types of EV Conversions

Electric vehicle (EV) conversions involve transforming conventional internal combustion engine (ICE) vehicles into electric-powered ones. This process is gaining traction as a sustainable transportation solution, offering environmental benefits and cost savings. The types of EV conversions vary based on the vehicle type, the components used, and the intended application. The conversion process typically involves replacing the ICE with an electric motor, integrating a battery pack, and modifying the vehicle's chassis to accommodate these components. Below are the key types of EV conversions identified from the research papers. The conversion of conventional vehicles to electric vehicles (EVs) can be categorized into full and partial conversions, each with distinct methodologies and benefits. Full conversions involve replacing the entire powertrain, while partial conversions focus on upgrading specific components. This overview will explore these types of conversions and highlight successful case studies.

A. Full Conversion

Electric vehicle (EV) conversion refers to the process of replacing a vehicle's internal combustion engine (ICE) with an electric motor and integrating a suitable battery system to power the drivetrains. This method enables traditional gasoline-powered vehicles to operate as fully electric models. The benefits of EV conversions are multifaceted. One of the primary environmental advantages is the substantial reduction in greenhouse gas emissions, contributing to cleaner air and climate change mitigation efforts. Additionally, electric powertrains inherently offer enhanced performance and greater energy efficiency compared to ICE systems, due to their instant torque delivery and simpler mechanical structure. A practical example of this approach can be seen in the United States, where many commercially available EVs are, in fact, full conversions of existing gasoline vehicles demonstrating the viability and effectiveness of conversion as an alternative to purchasing new factory-made EVs[51].

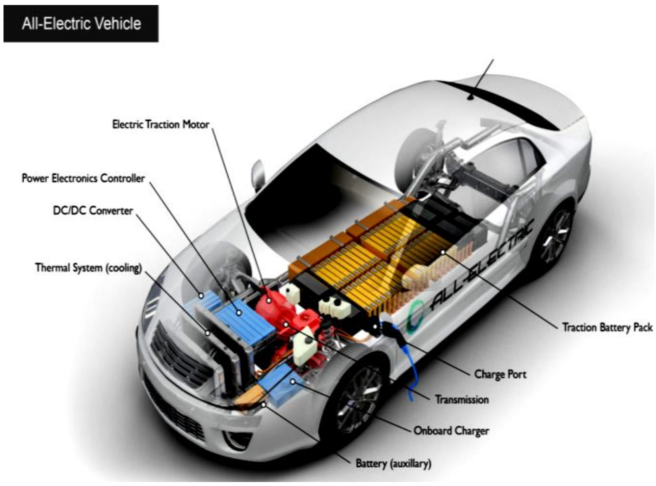

Fig2: Fully converted EVs

B. Partial Conversion

Electric vehicle (EV) retrofitting involves upgrading select components of an internal combustion engine (ICE) vehicle such as the battery, electric motor, or transmission, while retaining certain original ICE elements. Unlike full conversions, which completely replace the ICE system, retrofitting offers a more gradual approach to electrification. One of the main advantages of retrofitting is its cost-effectiveness. Since not all components are replaced, the overall expense is generally lower than that of a full EV conversion. Additionally, this method allows users to transition to electric mobility incrementally, making it more accessible for individuals and communities with limited financial resources or technical support. A practical example of retrofitting would be replacing a conventional vehicle's engine with a more efficient electric motor and battery system while preserving components such as the existing transmission or drivetrain [52]. This approach provides a balance between performance improvement and cost control.

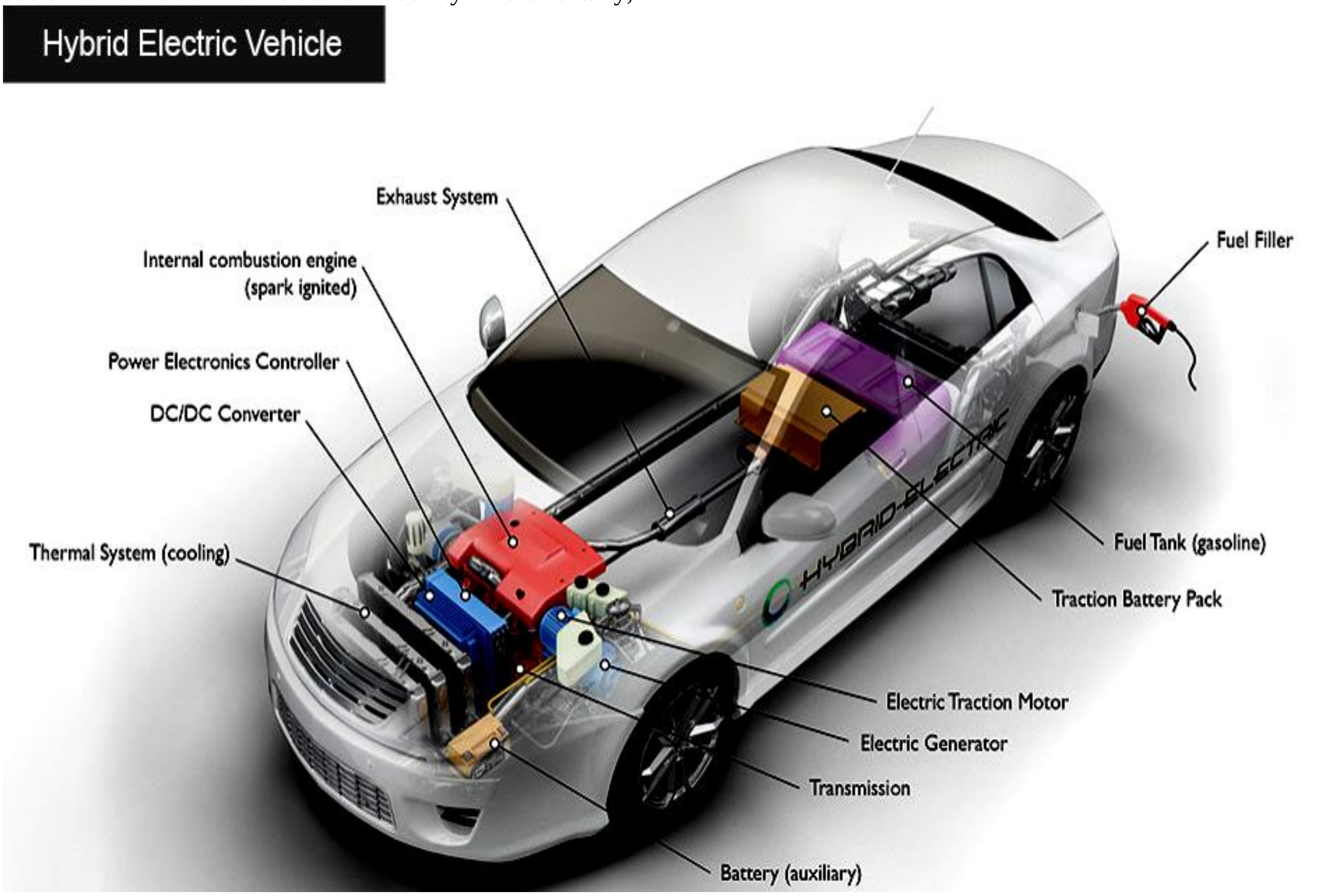

Fig3: Partial converted EVs

C. Case Studies

Numerous real-world examples highlight the growing interest and feasibility of electric vehicle (EV) conversions and retrofitting across different contexts. In academic settings, engineering students have undertaken full EV conversions as part of their capstone or final-year projects. These initiatives not only demonstrate the practicality of theoretical knowledge but also highlight the technical viability of converting internal combustion engine (ICE) vehicles into fully electric ones. Beyond educational environments, a large community of hobbyists and independent enthusiasts has emerged, documenting their personal EV conversion projects. These case studies provide valuable insights into various methods, component choices, and performance outcomes, enriching the collective knowledge base and encouraging wider adoption[53]. While full conversions present a robust and comprehensive solution for reducing emissions and achieving long-term sustainability, partial conversions or retrofitting offer a more flexible and affordable pathway. This approach is especially appealing for individuals and organizations seeking a gradual and budget-conscious transition to electric mobility.

4. Technical and Economic Challenges in EV Conversion

Electric vehicle (EV) conversion faces several technical and economic challenges, particularly concerning battery capacity, range limitations, and performance impact. These challenges are pivotal in determining the feasibility and attractiveness of EVs in the market. Battery technology advancements, such as lithium-ion and solid-state batteries, aim to increase energy density and improve performance, yet issues like capacity degradation and recycling remain significant hurdles. The economic aspect is influenced by the high initial costs and limited driving range, which are barriers to broader market penetration. Addressing these challenges requires innovative approaches and strategic policy frameworks to enhance battery capacity and reduce costs, thereby improving EV performance and range.

A. Battery Capacity and Range Limitations

Battery technology plays a central role in the performance and adoption of electric vehicles (EVs), with energy density being one of the most critical factors. Recent advancements in lithium-ion and emerging solid-state batteries aim to increase energy density, thereby extending driving range and improving overall vehicle efficiency. Despite these innovations, battery capacity degradation over time continues to pose challenges, affecting the long-term reliability and performance of EVs. In addition to technical limitations, the high initial cost of EV batteries remains a major obstacle to widespread adoption. Although ongoing developments in manufacturing efficiency and battery recycling technologies show promise in reducing these costs, affordability remains a pressing concern for both consumers and manufacturers. Driving range, directly influenced by battery energy density, continues to limit the practicality of EVs, particularly for long-distance travel. The current limitations in battery materials affect not only performance but also consumer confidence, underscoring the need for continued research and innovation in battery technology[54].

Performance Impact

The performance of electric vehicles (EVs) is significantly influenced by the longevity and efficiency of their batteries. One of the major factors affecting battery life is the charging rate. Fast charging, while convenient, can accelerate capacity degradation, particularly when paired with frequent use. This degradation can lead to reduced driving range, decreased efficiency, and ultimately, a shorter lifespan for the vehicle.

A promising solution to the challenge of battery degradation is the concept of second-life applications. Retired EV batteries can be repurposed for other uses, such as stationary energy storage systems, thereby extending their usefulness and reducing environmental impact. However, the effectiveness of this approach depends on addressing technical challenges, such as managing the inconsistent state of health and charge of retired batteries, to ensure reliability and performance[55]. While advancements in battery technology and recycling practices hold promise for mitigating some of these challenges, the economic and technical hurdles in EV conversion remain significant. To overcome these barriers, comprehensive strategies are required, including policy frameworks that support circular economy principles and infrastructure expansion to enable swappable battery systems, particularly in regions like India where such innovations could accelerate adoption.

B. Compatibility of Electric Powertrains with Existing Vehicle Structures

The conversion of internal combustion engine (ICE) vehicles to electric vehicles (EVs) presents several technical and economic challenges, particularly concerning the compatibility of electric powertrains with existing vehicle structures. These challenges encompass a range of issues from technical integration to economic feasibility, each requiring careful consideration to ensure successful conversion. The following sections detail these challenges and considerations.

C. Technical Challenges

Retrofitting a vehicle involves replacing the internal combustion engine (ICE) with an electric motor and battery system, but this requires significant modifications to ensure compatibility with the existing vehicle structure. These modifications include adjustments for battery placement and motor integration, which can be complex and technically demanding. Achieving this integration requires careful planning and precise engineering to ensure the new components fit and function optimally.

Another critical aspect of retrofitting is the effective management of power electronics and control systems. The interaction between energy storage systems (batteries) and power electronics converters must be precisely managed to ensure stable voltage, efficient current handling, and minimal switching losses. This requires advanced converter designs and sophisticated controller systems to maintain vehicle performance and safety. Lastly, meeting performance expectations after conversion is essential. This involves optimizing dynamic response and power delivery efficiency through the careful selection of components such as converters, controllers, and motors. Ensuring these systems work together smoothly is vital to maintaining the vehicle’s overall functionality and reliability[56].

D. Economic Challenges

The economic feasibility of converting internal combustion engine (ICE) vehicles into electric vehicles (EVs) is a major barrier to widespread adoption [57-60]. One of the most significant challenges is the high cost of components, such as batteries and electric motors, along with the labor required for the conversion process. When compared to the cost of purchasing new EVs, these conversion expenses can be prohibitive, particularly for individuals or businesses with limited budgets. Another economic challenge is the issue of regulatory compliance and standardization. The lack of standardized conversion kits, combined with the need to meet various regulatory standards, can increase both the complexity and cost of the conversion process. This challenge is further compounded by the lack of uniformity in charging infrastructure, which can result in additional expenses for consumers and service providers [61-65]. While converting ICE vehicles to EVs offers a promising pathway to sustainable transportation, addressing these economic challenges is crucial. Innovation in component design and regulatory frameworks will be necessary to make conversions more viable and accessible. Moreover, the development of standardized conversion kits and an expanded, consistent charging infrastructure could significantly reduce costs and enhance the feasibility of these projects.

E. Cost vs. Environmental and Economic Benefits

The relationship between costs and the environmental and economic benefits of various initiatives reveals a complex interplay where initial investments can lead to substantial long-term gains. Understanding this dynamic is crucial for policymakers and stakeholders aiming to balance economic growth with environmental sustainability. The following sections outline key aspects of this relationship.

F. Economic Costs of Environmental Health Issues

The economic feasibility of converting internal combustion engine (ICE) vehicles into electric vehicles (EVs) is a major barrier to widespread adoption. One of the most significant challenges is the high cost of components, such as batteries and electric motors, along with the labor required for the conversion process. When compared to the cost of purchasing new EVs, these conversion expenses can be prohibitive, particularly for individuals or businesses with limited budgets. Another economic challenge is the issue of regulatory compliance and standardization. The lack of standardized conversion kits, combined with the need to meet various regulatory standards, can increase both the complexity and cost of the conversion process. This challenge is further compounded by the lack of uniformity in charging infrastructure, which can result in additional expenses for consumers and service providers. While converting ICE vehicles to EVs offers a promising pathway to sustainable transportation, addressing these economic challenges is crucial. Innovation in component design and regulatory frameworks will be necessary to make conversions more viable and accessible. Moreover, the development of standardized conversion kits and an expanded, consistent charging infrastructure could significantly reduce costs and enhance the feasibility of these projects [66-70].

G. Cost-Benefit Analysis in Environmental Projects

Cost-benefit analysis (CBA) is a critical tool for evaluating projects, particularly in the field of environmental economics. It plays a vital role in determining the net present value (NPV) of initiatives, which helps decision-makers assess the feasibility and long-term impacts of various projects. This process involves comparing the costs of implementing a project against the expected benefits, providing a framework for making informed choices. Incorporating non-market benefits and environmental externalities into CBA can significantly enhance decision-making, particularly for long-term sustainability projects. By accounting for factors such as ecosystem services, climate change mitigation, and social welfare, CBA offers a more comprehensive assessment of the true value of a project. This approach is particularly useful when considering projects with long-term environmental impacts, as it ensures that both direct and indirect benefits are properly factored into the evaluation.

H. Economic Gains from Sustainable Practices

Adopting sustainable practices in various industries can lead to significant economic benefits alongside environmental improvements. One such example, the implementation of Cleaner Production Technology (CPT) in industries has proven effective in minimizing environmental impacts while simultaneously maximizing economic benefits. The textile sector in Pakistan, for instance, has demonstrated how CPT can optimize resource use, reduce waste, and enhance productivity, resulting in both environmental and economic gains. Similarly, the construction of green buildings, though often associated with higher initial costs, presents a compelling case for long-term economic viability. These buildings are designed to be energy-efficient and environmentally friendly, leading to substantial savings in energy costs over time. Additionally, green buildings offer health benefits that can improve productivity and reduce healthcare costs, making them a sustainable investment in the end. While the upfront costs of implementing environmentally friendly initiatives may seem high, the long-term economic and health benefits frequently outweigh these expenses. This suggests the need for a paradigm shift in how costs and benefits are perceived within environmental policy, encouraging a focus on long-term value rather than short-term expenditure[71].

5. Recent Advances in EV Conversion Technologies

Recent advancements in electric vehicle (EV) conversion technologies have significantly improved electric drivetrains and motors, enhancing overall vehicle performance and efficiency. Innovations in electric motor design, power electronics, and control strategies are pivotal in this evolution. The following sections detail these advancements

A. Improvements in Electric Drivetrains and Motors

Recent advancements in electric motor technologies have significantly improved the performance and efficiency of electric drivetrains in electric vehicles (EVs). One such innovation is the Permanent Magnet Synchronous Motor (PMSM), which has become increasingly popular due to its high efficiency and power density. These motors are particularly well suited for EV applications, offering better performance in terms of torque generation and energy efficiency. In addition to advancements in motor design, the development of advanced control techniques has further enhanced motor performance. Techniques such as Field Oriented Control (FOC) have revolutionized the control of electric motors by enabling precise torque control and improving the dynamic response of the motor. This results in smoother acceleration and better handling characteristics, which are critical for optimizing the driving experience in electric vehicles.

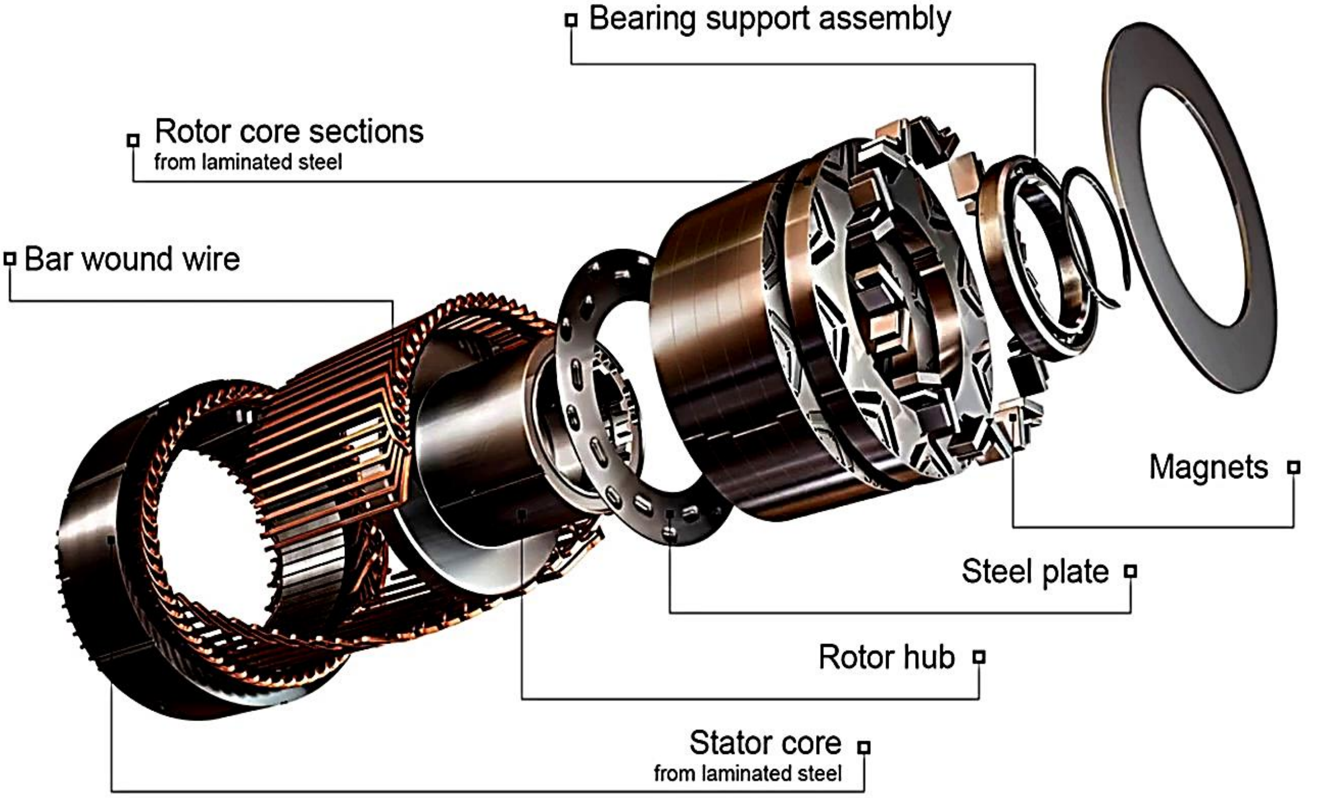

Fig4: Permanent Magnet Synchronous Motor

Recent advancements in power electronics have significantly contributed to the efficiency and reliability of electric drivetrains and power conversion systems in electric vehicles (EVs). One major innovation is the integration of wide band gap semiconductors, such as silicon carbide (SIC) and gallium nitride (GAN), into key components like inverters and onboard chargers. These semiconductors offer superior performance compared to traditional silicon-based devices, particularly in reducing energy losses and improving thermal management, which is crucial for maintaining system efficiency and preventing overheating. Additionally, the development of adaptive E-Gear control algorithms has further enhanced the performance of electric power converters. This innovative control strategy optimizes drivetrains reliability and energy efficiency by dynamically adjusting power distribution based on real-time driving conditions. As a result, it helps extend the lifespan of power electronics components, contributing to both the economic and environmental sustainability of electric vehicles[72].

As the electric vehicle (EV) industry continues to evolve, several emerging trends are expected to drive further advancements in electric drivetrains and motor technologies. One key direction is the development of modular powertrains architectures. These architectures are designed to be scalable and adaptable, allowing for more flexible EV designs that can accommodate different vehicle types and use cases. This modularity enables manufacturers to more efficiently develop and deploy new EV models, accelerating the advancement of electric drive trains. Another promising future development is the incorporation of artificial intelligence (AI) into motor control systems. AI-driven control strategies are poised to enhance EV performance by optimizing motor operation in real-time based on driving conditions. This would lead to improved efficiency, smoother performance, and better overall driving dynamics, making EVs even more attractive to consumers.

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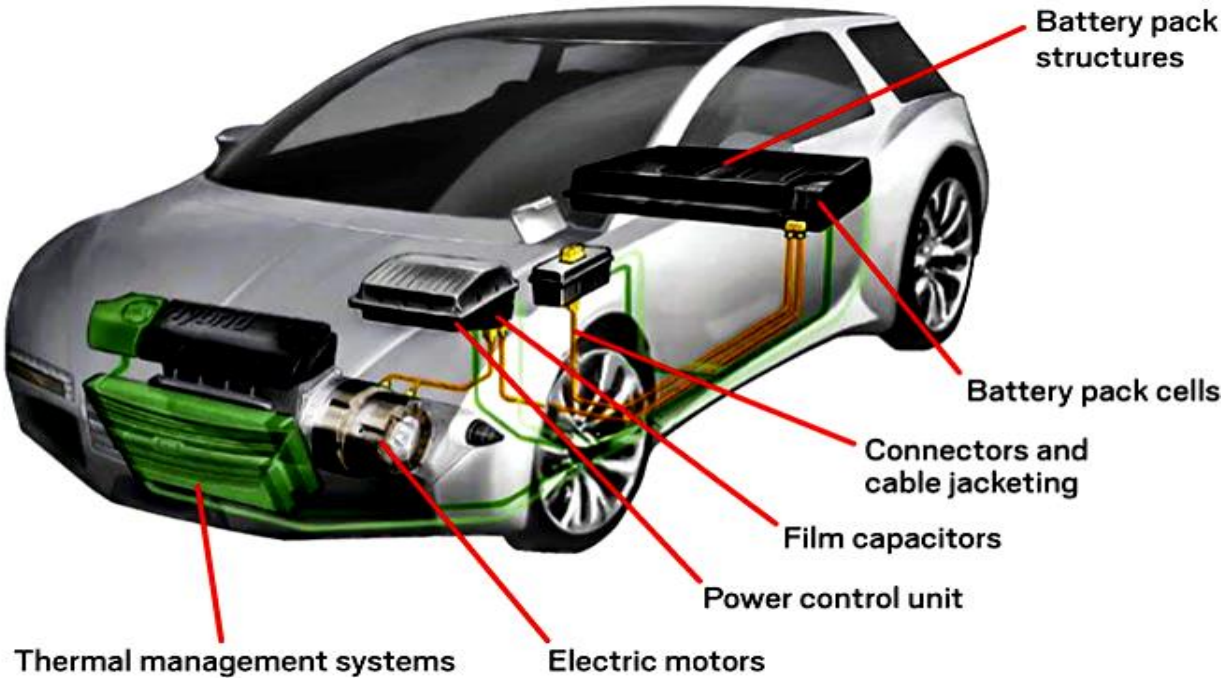

Fig5: Electric vehicle (EV) drivetrains system

While these advancements present a promising future for EV technology, challenges such as battery range and charging infrastructure remain critical areas for ongoing research and development. Addressing these issues will be essential for the widespread adoption of electric vehicles.

B. Innovations in Battery and Fast-Charge Technologies

Recent advancements in electric vehicle (EV) conversion technologies have significantly focused on innovations in battery and fast-Charge technologies. These developments aim to enhance charging efficiency, reduce time, and integrate renewable energy sources, thereby supporting the growing demand for electric mobility. Key innovations include various converter topologies and smart charging systems, which are essential for optimizing the charging process.

Advancements in fast charging technologies are key to enhancing the convenience and efficiency of electric vehicles (EVs). One significant development is the improvement of converter topologies, including Boost, Cuk, and bidirectional Vienna rectifiers. These advanced converters help improve charging efficiency by managing power flow more effectively, ensuring faster and more reliable charging. Another promising innovation is inductive charging, which uses wireless power transfer systems to enable dynamic charging without the need for physical connectors. This technology enhances user convenience by allowing vehicles to charge while in motion or parked, without the hassle of plugging in[73]. Additionally, battery-assisted charging stations have emerged as a novel solution to improve grid stability and reduce operational costs. These stations store energy to operate independently from the electrical grid, providing a more stable charging environment while lowering the burden on the grid.

Advancements in battery technologies have been pivotal in enhancing the overall performance and efficiency of electric vehicles (EVs). One significant development is the integration of bidirectional charging technologies, such as Vehicle-to-Grid (V2G) systems. These systems allow EVs to serve as energy storage units, enabling the transfer of energy both to and from the grid. This capability not only improves grid stability but also offers more flexible energy management options, helping to balance energy demand and supply. In addition, innovations in onboard charging systems, such as Multi-device Interleaved DC-DC Bidirectional Converters (MDIBC), have led to improvements in power density and compactness. These advancements facilitate faster and more efficient charging processes, reducing charging times and improving overall user convenience[74].

While these advancements present significant opportunities for enhancing EV infrastructure, challenges such as standardization, charging time optimization, and grid integration remain critical areas for future research and development. Addressing these challenges will be essential for the sustainable growth of the EV industry.

Fig6: Multi-device Interleaved DC-DC Bidirectional Converters

C. Integration of Renewable Energy Solutions in EV Charging

Recent advancements in electric vehicle (EV) conversion technologies have significantly integrated renewable energy solutions into EV charging systems. This integration not only enhances sustainability but also addresses challenges related to grid stability and power quality [75-79]. The following sections outline key developments in this area.

The integration of renewable energy sources into electric vehicle (EV) charging systems is a key advancement in promoting sustainable energy practices. Solar and wind energy systems have been optimized with the use of Maximum Power Point Tracking (MPPT) techniques, which ensure the efficient extraction and management of energy during the charging process. These techniques help maximize the amount of energy harvested from solar and wind sources, contributing to more efficient and environmentally friendly EV charging. Moreover, the incorporation of microgrid solutions has further enhanced energy management capabilities. Microgrids allow for better control and resilience in power systems, facilitating the integration of distributed energy resources (DERs). This integration not only optimizes power generation and consumption but also provides increased flexibility and reliability in energy supply, making EV charging more sustainable and efficient[80].

Advancements in charging technologies are crucial to addressing the challenges of electric vehicle (EV) adoption, particularly in terms of reducing charging times and improving grid interaction. One key innovation is high-power fast charging, which utilizes advanced converter topologies such as Boost and bidirectional converters. These topologies significantly enhance charging efficiency and reduce the time required for a full charge, making EVs more convenient for consumers and accelerating their widespread adoption. Additionally, bidirectional charging technologies, including Vehicle-to-Grid (V2G) systems, are gaining prominence. V2G enables EVs to return energy to the grid, thus helping balance electricity loads and improving grid stability, particularly during peak demand periods. This integration not only enhances the sustainability of EVs but also contributes to a more resilient and flexible energy system[81].

The integration of renewable energy sources into electric vehicle (EV) charging infrastructure offers significant benefits, but it also presents several challenges that need to be addressed for effective implementation. One major issue is power quality, as the variability of renewable energy generation can lead to voltage fluctuations and harmonic distortions. To mitigate these issues and maintain system stability, advanced control methods and adaptive filtering techniques are essential. Additionally, energy storage solutions are critical to overcoming the intermittent nature of renewable energy. Energy storage systems, such as batteries, provide a stable energy supply for EV charging, ensuring that fluctuations in renewable energy generation do not disrupt the charging process. While these challenges exist, addressing them through technological advancements and proper infrastructure planning is vital for the successful integration of renewable energy into EV charging systems, paving the way for more sustainable and resilient transportation networks.

6. Latest Research Findings on EV Conversions

A. Efficiency Analysis of Converted EVs vs. Factory-Made EVs

The efficiency analysis of converted electric vehicles (EVs) versus factory-made EVs reveals significant insights into performance, cost, and technological advancements. Converted EVs, often retrofitted from internal combustion engine vehicles, can achieve competitive efficiency levels through strategic modifications. The following sections outline key aspects of this comparison.

Converted electric vehicles (EVs) have demonstrated significant improvements in energy efficiency, making them a viable alternative to traditional internal combustion engine vehicles. Research has shown that these conversions can lead to optimized energy consumption, with measurable gains in performance post-conversion. Enhancements in vehicle design also contribute to efficiency gains. Modifications such as reducing vehicle weight, minimizing aerodynamic drag, and lowering rolling resistance have been reported to improve overall efficiency by up to 18%. These adjustments are particularly important in maximizing the potential of retrofitted EVs[82].Furthermore, tailoring conversions to specific driving conditions and cycles can yield substantial performance benefits. For instance, adapting retrofitted EVs to particular urban or delivery routes has been shown to increase daily travel distances by as much as 32.1%, highlighting the practical advantages of context-specific design.

Recent technological advancements have significantly improved the performance and efficiency of electric vehicle systems, particularly through innovations in power electronics and control. One notable development is the use of advanced semiconductor materials such as silicon carbide (SIC) and gallium nitride (GAN) in power conversion systems. These materials are known for their superior thermal conductivity and high-frequency switching capabilities, which substantially reduce thermal losses and improve energy efficiency across the drivetrain. In parallel, the implementation of sophisticated control algorithms and enhanced thermal management systems plays a crucial role in optimizing power flow and ensuring the reliability and longevity of critical components. These control strategies allow for real-time adjustments in energy distribution, effectively balancing performance with energy conservation[83].

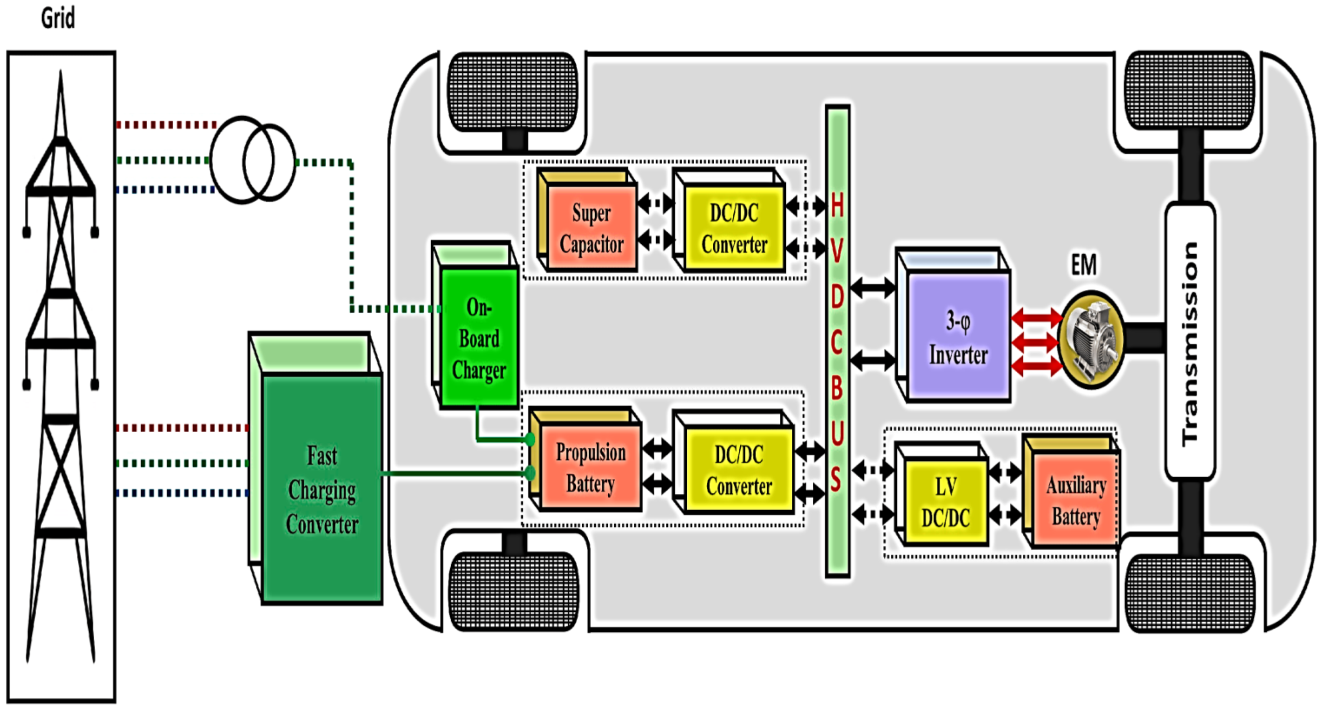

Fig7: Power Conversion System

While converted EVs present a viable alternative with notable efficiency benefits, factory-made EVs often leverage cutting-edge technology and design from inception, potentially offering superior performance and reliability in the long term.

B. Impact of Conversion on Energy Consumption and Carbon Emissions

The conversion of traditional energy systems to more sustainable alternatives significantly influences energy consumption and carbon emissions. This transition is crucial for addressing climate change, as evidenced by various studies highlighting the benefits of electric vehicles and alternative energy sources. The following sections detail the effects of conversion on energy use and emissions.

Electric vehicle (EV) conversions present a substantial opportunity for energy cost reduction and environmental impact mitigation. According to recent studies, EVs can reduce energy expenses by up to 7.7 times when compared to traditional internal combustion engine (ICE) vehicles, primarily due to the higher efficiency of electric drivetrains and the lower cost of electricity relative to fossil fuels. This potential extends beyond road transport. In the context of regional railways, the transition from diesel-powered systems to battery-electric systems powered by green electricity has demonstrated energy savings ranging from 65% to 71%. These figures highlight the broader applicability and effectiveness of electrification in reducing overall energy consumption in transportation systems[84].

The electrification of vehicles, particularly through conversion, plays a vital role in reducing greenhouse gas (GHG) emissions. Studies show that converted electric motorcycles emit four times fewer GHGs than their internal combustion engine (ICE) counterparts, making them a significantly cleaner alternative for urban mobility. In addition, integrating hydrogen produced from green electricity into hybrid-electric configurations can further enhance environmental performance. This approach has the potential to achieve up to a 90% reduction in GHG emissions, highlighting the transformative impact of clean energy sources in sustainable transportation[85].

The shift toward renewable energy is not only an environmental necessity but also a strategic economic and policy imperative, particularly for developing nations. For instance, Indonesia has committed to achieving net-zero emissions by 2060, underlining the urgency of transitioning from fossil fuels to sustainable energy systems. Furthermore, empirical evidence indicates a strong positive correlation between economic growth, energy consumption, and carbon emissions. This relationship reinforces the importance of adopting sustainable energy practices to decouple economic development from environmental degradation[86]. Conversely, while conversion technologies present significant benefits, challenges such as high initial costs and the need for supportive infrastructure remain critical barriers to widespread adoption.

C. Long-Term Performance and Durability of EV Conversion Batteries

The long-term performance and durability of electric vehicle (EV) conversion batteries are critical for their viability and acceptance in the market. Research indicates that various factors, including temperature, charge and discharge rates, and usage patterns, significantly influence battery lifespan. The following sections detail these aspects.

Accurate estimation of battery lifespan is critical for assessing the long-term viability and performance of electric vehicles (EVs). Utilizing the Arrhenius mathematical model, researchers have predicted that lithium-ion battery packs can operate for approximately 6,000 hours at lower temperatures (25°C) and around 3,000 hours at elevated temperatures (60°C), assuming specific charge and discharge conditions. These findings highlight the significant impact of thermal environments on battery degradation rates. In the context of lead-acid batteries, performance varies by design. A recent study showed that Absorbent Glass Mat (AGM) batteries successfully sustained a five-year usage interval without failure, whereas Flooded Lead-acid (FLD) batteries failed to meet a minimum operational requirement of three years[87]. These results emphasize the importance of selecting appropriate battery technologies based on application-specific demands and expected service conditions.

Battery capacity degradation is a key concern affecting the long-term performance and reliability of electric vehicles (EVs). Real-world performance tests indicate that EV batteries can lose approximately 4% of their capacity after 10,000 km of driving, with this figure rising to nearly 14% after 45,000 km. These findings underscore the impact of continuous cycling and mileage accumulation on battery health. Conversely, lithium titanate batteries often used in stationary grid operations demonstrated superior longevity. One study reported less than 10% capacity loss over a seven-year period, suggesting a potential operational lifespan exceeding 15 years under controlled usage conditions[88]. This highlights the significance of battery chemistry in determining degradation rates and long-term viability. While these findings highlight the durability of certain battery types, it is essential to consider that performance can vary significantly based on environmental conditions and usage patterns, which may lead to different degradation rates across battery technologies.

7. Research Gaps and Future Trends

The transition to electric vehicles (EVs) and the conversion of existing vehicles into electric models present significant opportunities for reducing greenhouse gas emissions. However, there are notable research gaps and a pressing need for standardized guidelines and regulations to assess the lifecycle impacts of converted EVs. This response outlines the critical areas for future research and policy recommendations to facilitate the adoption of EV conversions.

A. Research Gaps in Lifecycle Assessment

Despite the growing interest in electric vehicle (EV) conversions as a sustainable mobility solution, several research gaps remain in lifecycle assessment (LCA) practices. One major issue is the lack of standardized LCA methodologies, which leads to discrepancies and inconsistencies in evaluating the environmental impacts of converted EVs across studies. Without a uniform framework, it becomes difficult to make accurate comparisons or inform policy decisions. Furthermore, there is a scarcity of comprehensive data regarding emissions and energy consumption specific to vehicle conversions, as most existing datasets focus on factory-manufactured EVs[89]. This gap limits the ability to fully assess the environmental benefits or trade-offs of conversion practices. Another critical concern is the underexplored impact of battery production, which can represent a substantial portion of a vehicle's total lifecycle emissions. More focused research is needed to quantify these effects within the context of retrofitted vehicles, particularly when comparing reused versus newly manufactured battery systems.

B. Future Trends in Policy Recommendations

To accelerate the transition toward sustainable mobility, future policies must adopt a more inclusive and forward-thinking approach. One key recommendation is the implementation of financial incentives and infrastructure support to encourage the conversion of internal combustion engine vehicles to electric powertrains, particularly in regions with limited access to factory-made EVs. These incentives can lower the entry barrier and promote wider adoption of retrofitting practices. Additionally, maximizing the environmental benefits of EV deployment requires integrating renewable energy sources into the electricity grid that powers these vehicles. Policies should prioritize clean energy adoption to ensure that the shift to electrification translates into actual emissions reduction. Moreover, a shift toward lifecycle-based regulatory frameworks is essential. By considering the full supply chain from raw material extraction and battery production to end-of-life vehicle management governments can better address the hidden environmental costs associated with both new and converted EVs[90].While the focus on new EV production is critical, the potential of vehicle conversions should not be overlooked. Addressing these gaps and implementing robust policies can significantly enhance the sustainability of the transportation sector.

8. Conclusion and Future Recommendations

The research on converting internal combustion engine vehicles to electric vehicles (EVs) highlights significant advancements in technology and strategies to enhance conversion efficiency and reduce costs. Key findings emphasize the integration of cutting-edge electric powertrain components, power electronics, and battery storage systems, which collectively contribute to reducing the environmental footprint and optimizing energy efficiency. The use of supercapacitor banks and efficient battery cooling systems are particularly noted for their role in improving energy storage and usage, thereby supporting the global shift towards sustainable transportation. Transitioning to the strategies for enhancing conversion efficiency and reducing costs, several approaches are recommended.

A. Strategies to Enhance Conversion Efficiency and Reduce Costs

Improving the efficiency and affordability of electric vehicle (EV) conversions requires the integration of advanced technologies and system optimizations. One effective strategy is the use of state-of-the-art electric powertrain components and power electronics, which can significantly enhance vehicle performance, energy efficiency, and overall reliability during retrofitting processes. Another promising approach involves the deployment of supercapacitor banks. These systems can supplement traditional batteries by offering rapid energy discharge capabilities, thereby reducing the load on lithium-ion batteries and improving acceleration performance and energy recovery during braking. Moreover, developing efficient battery cooling systems is essential for maintaining battery health and operational stability. Proper thermal management not only extends battery life but also reduces long-term maintenance and replacement costs, making EV conversions more economically viable[91].

B. Suggested Future Research to Improve EV Conversion Sustainability

To enhance the sustainability of EV conversions, future research should focus on several key areas. First, exploring new materials for battery and powertrain components is essential to reduce both costs and environmental impact. Investigating alternative materials could lead to more efficient, less resource-intensive production processes. Additionally, conducting policy and economic analyses on the viability of large-scale EV conversions is critical to supporting both industry and government decisions in this area. This would provide a clearer understanding of the economic implications and the necessary policy frameworks to facilitate widespread adoption. By encouraging partnerships between industries, governments, and financial institutions, we can accelerate progress toward sustainable EV solutions[92].

This research provides a robust framework for EV conversion, it is essential to consider the broader implications of these technologies on the environment and economy. Future studies should focus on the long-term sustainability of these solutions and explore potential challenges in their widespread adoption. This holistic approach will ensure that the transition to electric vehicles is both economically viable and environmentally responsible.

References:

[1] M. Elkelawy, H. Alm ElDin Mohamad, E. Abd Elhamid, and M. A. El-Gamal, "A Critical Review of the Performance, Combustion, and Emissions Characteristics of PCCI Engine Controlled by Injection Strategy and Fuel Properties," *Journal of Engineering Research*, vol. 6, pp. 96-110, 2022.

[2] H. Bastawissi, Z. Yu-Sheng, M. Elkelawy, and A. Bastawissi, "Detailed 3D-CFD/chemistry of CNG-hydrogen blend in HCCI engine," SAE Technical Paper 0148-7191, 2010.

[3] M. Elkelawy, H. A.-E. Bastawissi, A. K. Abdel-Rahman ,A. Abou El-Yazied, and S. Mostafa El malla, "Effect of multifunctional fuel additive in diesel/waste oil biodiesel blends on industrial burner flame performance and emission characteristics," *International Journal of Ambient Energy*, vol. 44, pp. 1382-13.2023 31/12/2023 ,95

[4] S. El-din H. Etaiw, M. Elkelawy, I. Elziny, M. Taha, I. Veza, and H. Alm-Eldin Bastawissi, "Effect of nanocomposite SCP1 additive to waste cooking oil biodiesel as fuel enhancer on diesel engine performance and emission characteristics," *Sustainable Energy Technologies and Assessments*, vol. 52, p. 102291, 2022/08/01/ 2022.

[5] A. E. Kabeel, M. Elkelawy, H. A. E. Bastawissi, and A. M. Elbanna, "An experimental and theoretical study on particles-in-air behavior characterization at different particles loading and turbulence modulation," *Alexandria Engineering Journal*, vol. 58, pp. 451-465, 2019/06/01/ 2019.

[6] M. Elkelawy, A. Kamel, A. Abou-elyazied, and S. M. El-malla, "Experimental investigation of the effects of using biofuel blends with conventional diesel on the performance, combustion, and emission characteristics of an industrial burner," *Egyptian Sugar Journal,* vol. 19, pp. 44-59, 2022.

[7] M. Elkelawy, H. Alm ElDin Mohamad, A. K. Abdel-Rahman, A. Abou Elyazied, and S. Mostafa El Malla, "Biodiesel as an Alternative Fuel in Terms of Production, Emission, Combustion Characteristics for Industrial Burners: a Review," *Journal of Engineering Research,* vol. 6, pp. 45-52, 2022.

[8] H. Thakkar, K. k. Sadasivuni, P. V. Ramana, H. Panchal, M. Suresh, M. Israr*, et al.*, "Comparative analysis of the use of flash evaporator and solar still with a solar desalination system," *International Journal of Ambient Energy,* vol. 43, pp. 1561-1568, 2022/12/31 2022.

[9] A. M. Elbanna, C. Xiaobei, Y .Can, M. Elkelawy, and H. A.-E. Bastawissi, "A comparative study for the effect of different premixed charge ratios with conventional diesel engines on the performance, emissions, and vibrations of the engine block," *Environmental Science and Pollution Research,* vol. 30, pp. 106774-106789, 2023/10/01 2023.

[10] M. Elkelawy, H. Alm ElDin Mohamad, M. Samadony, A. M. Elbanna, and A. M. Safwat, "A Comparative Study on Developing the Hybrid-Electric Vehicle Systems and its Future Expectation over the Conventional Engines Cars," *Journal of Engineering Research,* vol. 6, pp. 21-34, 2022.

[11] H. A. E.-D. Bastawissi and M. Elkelawy, "Computational Evaluation of Nozzle Flow and Cavitation Characteristics in a Diesel Injector," *SAE International Journal of Engines* ,vol. 5, pp. 1605-1616, 2012.

[12] A. Hagar, El-Din, Y.-S. 张. Zhang, and E. Medhat, "A Computational Study of Cavitation Model Validity Using a New Quantitative Criterion," *Chinese Physics Letters,* vol. 29, p. 064703, 2012/06/01 2012.

[13] A. E. Kabeel, M .Elkelawy, H. A. El-Din, A. M. El-Banna, R. Sathyamurthy, and N. Prakash, "COMPUTATIONAL STUDY OF DIFFERENT TURBULENCE MODELS FOR AIR IMPINGEMENT JET INTO MAIN AIR CROSS STREAM," vol. 46, pp. 459-475, 2019-10-16 2019.

[14] M. M. El-Sheekh, A. A. El-Nagar ,M. ElKelawy, and H. A.-E. Bastawissi, "Bioethanol from wheat straw hydrolysate solubility and stability in waste cooking oil biodiesel/diesel and gasoline fuel at different blends ratio," *Biotechnology for Biofuels and Bioproducts,* vol. 16, p. 15, 2023/0.2023 01/2

[15] M. Elkelawy, H. A.-E. Bastawissi, A. M. Radwan, M. T. Ismail, and M. El-Sheekh, "Chapter 15 - Biojet fuels production from algae: conversion technologies, characteristics, performance, and process simulation," in *Handbook of Algal Biofuels* ,M. El-Sheekh and A. E.-F. Abomohra, Eds., ed: Elsevier, 2022, pp. 331-361.

[16] M. Elkelawy, H. A.-E. Bastawissi, E. El Shenawy, and M. Soliman, "Effect of Organic Compounds Additives for Biodiesel Fuel blends on Diesel Engine Vibrations and Noise Characteristics," *Journal of Engineering Research (ERJ,* vol. 8, p. 22, 2024.

[17] M. Elkelawy, E. A. El Shenawy, H. A. E. Bastawissi, and I. A. El Shennawy, "The effect of using the WCO biodiesel as an alternative fuel in compression ignition diesel engine on performance and emissions characteristics," *Journal of Physics: Conference Series,* vol. 2299, p. 012023, 2022/07/01 2022.

[18] M. Elkelawy, E. El Shenawy, H. Alm-EldinBastawissi, I. A. Mousa, and M. M. A.-R. Ibrahim, "Effects of Fuel Equivalence Ratio and Swirl Vane Angles on Premixed Burner Turbulent Flame Combustion Characteristics," *Journal of Engineering Research,* vol. 7, p. 15, 2024.

[19] M. Elkelawy, H. A.-E. Bastawissi, M. O. Elsamadony, and A. S. Abdalhadi, "Engine Performance and Emissions Improvement Study on Direct Injection of Diesel/Ammonia Dual Fuel by Adding CNG as Partially Premixed Charge," *Journal of Engineering Research,* vol. 7, p. 12, 2024.

[20] E. El Shenawy, H. A.-E. Bastawissi, and M. M. Shams, "Enhancement of the performance and emission attributes for the diesel engine using diesel-waste cooking oil biodiesel and graphene oxide nanofluid blends through response surface methodology," *Mansoura Engineering Journal,* vol. 49, p. 8, 2024.

[21] M. Elkelawy, "Experimental Investigation of Intake Diesel Aerosol Fuel Homogeneous Charge Compression Ignition (HCCI) Engine Combustion and Emissions," *Energy and Power Engineering,* vol. Vol.06No.14, p. 14, 2014.

[22] Y. Mohamed, F. Muhammad, Ezzat, M. Mohamed A, E. Medhat, and M. Y. Ismail, Ismaiel, "Experimental Investigation of the Performance and Exhaust Emissions of a Spark-Ignition Engine Operating with Different Proportional Blends of Gasoline and Water Ammonia Solution," *Journal of Engineering Research,* vol. 5, 2021.

[23] E. Medhat, A. E .El- Shenawy, A. Hagar, El-Din Moham, and K. Salma, Abd-AlMonem, "Experimental Investigation on Spray Characteristics of Waste-Cooking-Oil Biodiesel/Diesel Blends at Different Injection Parameters," *Engineering Research Journal (ERJ),* vol. 4, 2019.

[24] M .ElKelawy, H. A.-E. Bastawissi, E.-S. A. El-Shenawy, H. Panchal, K. Sadashivuni, D. Ponnamma*, et al.*, "Experimental investigations on spray flames and emissions analysis of diesel and diesel/biodiesel blends for combustion in oxy-fuel burner," *Asia-Pacific Journal of Chemical Engineering,* vol. 14, p. e2375, 2019.

[25] J. G. Vaghasia, J. K. Ratnadhariya, H. Panchal, K. K. Sadasivuni, D. Ponnamma, M. Elkelawy*, et al.*, "Experimental performance investigations on various orientations of evacuated double absorber tube for solar parabolic trough concentrator," *International Journal of Ambient Energy,* vol. 43, pp. 492-499, 2022/12/31 2022.

[26] M. E. P. D. Eng and I. A. M. Eng, "Experimental Study on the Impact of Secondary Air Injection and different swirl van angles on Premixed Turbulent Flame Propagation and Emission Behaviors," *Journal of Engineering Research (ERJ),* vol. 7, 2024.

[27] H. A. El-Din, M. Elkelawy, and Z. Yu-Sheng, "HCCI engines combustion of CNG fuel with DME and H 2 additives," *SAE Technical Paper 2010-01-1473,* 2010.

[28] S. Vivek, K. Srinivasan, B. Sharmila, Y. Dharshan, H. Panchal, M. Suresh*, et al.*, "An Improved Quality Inspection of Engine Bearings Using Machine Vision Systems," *Smart and Sustainable Manufacturing Systems,* vol. 6, pp. 86-9.2022 ,8

[29] M. H. Aboubakr, M. Elkelawy, H. A.-E. Bastawissi, and A. R. El-Tohamy, "The influence of using HHO with sunflower and soybean oil biodiesel/diesel blend on PCCI engine characteristics," *Journal of Engineering Research,* vol. 7, p. 15, 2024.

[30] A. M. Elbanna, X. Cheng, C. Yang, M. Elkelawy, and H. Alm-Eldin Bastawissi, "Investigative research of diesel/ethanol advanced combustion strategies: A comparison of Premixed Charge Compression Ignition (PCCI) and Direct Dual Fuel Stratification (DDFS ",(*Fuel,* vol. 345, p. 128143, 2023/08/01/ 2023.

[31] M. M. El-Sheekh, A. A. El-Nagar, M. ElKelawy, and H. A.-E. Bastawissi, "Maximization of bioethanol productivity from wheat straw, performance and emission analysis of diesel engine running with a triple fuel blend through response surface methodology," *Renewable Energy,* vol. 211, pp. 706-722, 2023/07/01/ 2023.

[32] H. Alm ElDin Mohamad, M. Elkelawy, and O. A. I. HENDAWI, "An overview of the Effect of using HHO on Spark ignition and direct injection engines combustion, performances, and emissions characteristics," *Journal of Engineering Research,* vol. 6, pp. 240-246, 2022.

[33] M. H. Aboubakr, M. Elkelawy, H. A.-E. Bastawissi, and A. R. El-Tohamy, "A technical survey on using oxyhydrogen with biodiesel/diesel blend for homogeneous charge compression ignition engine," *Journal of Engineering Research (ERJ,* vol. 8, 2024.

[34] S. F. Abd El Fattah, M. F. Ezzat, M. A. Mourad, M. Elkelawy, and I. M. Youssef, "Experimental Investigation of the Performance and Exhaust Emissions of a Spark-Ignition Engine Operating with Different Proportional Blends of Gasoline and Water Ammonia Solution," *Journal of Engineering Research,* vol. 5, pp. 38-45, 2022.

[35] M. Elkelawy, Z. Yu-Sheng, H. El-Din, Y. Jing-Zhou, A. El Zahaby, and E. El Shenawy, "Experimental Study on Flash Boiling and Micro-Explosion of Emulsified Diesel Fuel Spray Droplets by Shadowgraph Technology," *Transactions of CSICE,* vol. 27, pp. 306-308, 2009.

[36] M. Elkelawy, E. S. A. El Shenawy, H. A. Bastawissi ,and M. M. Shams. (2023, Impact of Carbon Nanotubes and Graphene Oxide Nanomaterials on the Performance and Emissions of Diesel Engine Fueled with Diesel/Biodiesel Blend. *Processes 11(11* .(

[37] M. Elkelawy, H. Alm ElDin Mohamad, M. Samadony, and A. S. Abdalhadi, "Impact of Utilizing a Diesel/Ammonia Hydroxide Dual Fuel on Diesel Engines Performance and Emissions Characteristics," *Journal of Engineering Research,* vol. 7, pp. 262-271, 2023.

[38] A. E. Kabeel, M. Elkelawy, H. A.-E. Mohamad, A. M. Elbanna, H .Panchal, M. Suresh*, et al.*, "The influences of loading ratios and conveying velocity on gas-solid two phase flow characteristics: a comprehensive experimental CFD-DEM study," *International Journal of Ambient Energy,* vol. 43, pp. 2714-2726, 2022/12/31 20.22

[39] H. A.-E. Bastawissi and M. Elkelawy, "Investigation of the Flow Pattern inside a Diesel Engine Injection Nozzle to Determine the Relationship between Various Flow Parameters and the Occurrence of Cavitation," *Engineering,* vol. Vol.06No.13, p. 13 , .2014

[40] H. Alm El-Din, M. Elkelawy, and A. E. Kabeel, "Study of combustion behaviors for dimethyl ether asan alternative fuel using CFD with detailed chemical kinetics," *Alexandria Engineering Journal,* vol. 56, pp. 709-719, 2017/12/01/ 2017.

[41] F. Zainuri, D. A. D. AS, M. Adhitya, R. Subarkah, R. Filzi, T. Rahmiati*, et al.*, "Analytical Conversion of Conventional Car to Electric Vehicle Using 5KW BLDC Electric Motor," *Jurnal Penelitian Pendidikan IPA,* vol. 10, pp. 6703-6708, 2024.

[42] A. Patlins, A .Hnatov, S. Arhun, H. Hnatova, and O. Saraiev, "Features of converting a car with an internal combustion engine into an electric car," in *2022 IEEE 7th International Energy Conference (ENERGYCON)*, 2022, pp. 1-6.

[43] S. G. Liasi, F. Kardan, and M. T. Bina" ,Power Electronics Converters for EVs and Wireless Chargers: An Overview on Existent Technology and Recent Advances," *Power Electronics for Green Energy Conversion,* pp. 475-517, 2022.

[44] B. John, M. Prajul, J. V. Jose, K. Sujay, and P. Jayadevan, "Design, Simulation and Analysis of Components for Electric Auto Conversion," *ARAI Journal of Mobility Technology,* vol. 2, pp. 131-139, 2022.

[45] V. Dimitrov and A. Nikolov, "Comparative Analysis at Converting Electric Vehicles," in *2023 4th International Conference on Communications, Information, Electronic and Energy Systems (CIEES)*, 2023, pp. 1-5.

[46] M. Elkelawy, E. El Shenawy, H. Alm-EldinBastawissi, I. A. Mousa, and M. M. A.-R. Ibrahim, "Analyzing the Influence of Design and Operating Conditions on Combustion and Emissions in Premixed Turbulent Flames: A Comprehensive," *Journal of Engineering Research (ERJ,* vol. 8, p. 15, 2024.

[47] M. H. Aboubakr, M. Elkelawy, H. A.-E. Bastawissi, and A. R. Abd Elbar, "Chemical Kinetic Investigation: Exploring the Impact of Various Concentrations of HHO Gas with a 40% Biodiesel/Diesel Blend on HCCI Combustion," *Journal of Engineering Research,* vol. 8, 2024.

[48] M. Elkelawy, M. Bassuoni, H. A.-E. Bastawissi, and S. I. Haiba, "Effect of Dual-fuelled CNG and Gasoline on Spark Ignition engine performance and Emissions behaviors at different loads," *Journal of Engineering Research,* vol. 8, p. 18, 2025.

[49] C. Duangtongsuk, T. Thianthamthita, R. Pupadubsin, N. Chayopitak, and W. Kongprawechnon, "EV conversion performance analysis and sizing of traction motor and battery from driving cycles," in *2022 19th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 2022, pp. 1-6.

[50] M. Embrandiri, D .Isa, and R. Arehli, "An Electric Vehicle Conversion using Batteries and Ultracapacitors Preliminary Performance Investigation," *Journal of Asian Electric Vehicles,* vol. 9, pp. 1521-1527, 2011.

[51] J. Yu and K. Lee, "Analysis of Conducted Emission EM Noise in High Voltage Power Conversion Systems for Electric Vehicle," in *2024 International Conference on Electromagnetics in Advanced Applications (ICEAA)*, 2024, pp. 012-012.

[52] D. Rimpas and P. Chalkiadakis, "Electric vehicle transmission types and setups: A general review," *International Journal of Electric and Hybrid Vehicles,* vol. 13, pp. 38-56, 2021.

[53] A. Eydgahi and E. L. Long, "Converting an internal combustion engine vehicle to an electric vehicle," in *2011 ASEE Annual Conference & Exposition* ,2011 ,pp. 22.381. 1-22.381. 15.

[54] H. Roy, B. N. Roy, M. Hasanuzzaman, M. S. Islam, A. S. Abdel-Khalik, M. S. Hamad*, et al.*, "Global advancements and current challenges of electric vehicle batteries and their prospects: a comprehensive review," *Sustainability,* vol. 14, p. 16684, 2022.

[55] M. K. Al-Alawi, J. Cugley, and H. Hassanin, "Techno-economic feasibility of retired electric-vehicle batteries repurpose/reuse in second-life applications: A systematic review," *Energy and Climate Change,* vol. 3, p. 1.2022 ,00086

[56] M. Deepak and L. S. Malladi, "Analysis of Critical Issues in Retrofitting of IC Vehicles to Electric Vehicle: A Technical Review," in *2023 International Conference on Advanced & Global Engineering Challenges (AGEC)*, 2023, pp. 137-140.

[57] M. ELKELAWY, A. M. SAEED, and H. SELEEM, "Egypt's Solar Revolution: A Dual Approach to Clean Energy with CSP and PV Technologies," *Pharos Engineering Science Journal (PES),* vol. 1, pp. 29-37, 2025.

[58] A. A. El-Nagar, M. M. El-Sheekh, M. Elkelawy, and H. A.-E. Bastawissi, "Enhancing diesel engine performance and emissions with innovative Ethanol-Surfactant blends in Biodiesel: Unveiling insights through fractional factorial design," *Sustainable Energy Technologies and Assessments,* vol. 73, p. 104169.2025 ,

[59] M. Elkelawy, H. A.-E. Bastawissi, M. O. Elsamadony, and A. Salem, "Enhancing Diesel Engine Performance by Directly Injecting Blends of Ammonium Hydroxide and Including Liquid Petroleum Gas as a Partially Premixed Charge," *Journal of Engineering Research (ERJ,* vol. 8, p. 16, 2024.

[60] D. S. Flaih, M. F. Al-Dawody, M. Elkelawy, W. Jamshed, A. Abd-Elmonem, N. S. E. Abdalla*, et al.*, "Experimental and numerical study on the characteristics of gasoline engine powered by gasoline blended with water ammonia solution," *Fuel,* vol. 387, p. 134333, 2025.

[61] A. Garg, T. Pattnaik, S. R. Verma, M. S. Ballal, M. G. Wath, and S. A. Wakode, "Addressing Challenges and Promoting Standardization in EVCS: A Review," in *2023 IEEE 3rd International Conference on Smart Technologies for Power, Energy and Control (STPEC)*, 2023, pp. 1-6.

[62] M. Elkelawy, H. A.-E. Bastawissi, A. Abou El-Yazied, and S. El-malla, "Experimental Investigation on Combustion and Emission Characteristics of Co-combustion of Pulverized Biomass with Diesel Fuel in an Industrial Burner," *Journal of Engineering Research,* vol. 8, p. 17, 2024.

[63] M. H. Aboubakr, H. A.-E. Bastawissi, and A. R. Abd Elbar, "Exploring the Influence of Various Factors, Including Initial Temperatures, Equivalence Ratios, and Different Biodiesel/Diesel Blend Ratios, on Homogeneous Charge Compression Ignition (HCCI) Combustion," *Journal of Engineering Research (ERJ),* vol. 8, p. 8, 2024.

[64] M. ELKELAWY, W. M. EL-ASHMAWY, A. W. AHMED, and H. SELEEM, "Feasibility Study of Geothermal Energy Development in Egypt: Power Generation and Direct Use in Gulf of Suez, Red Sea, and Western Desert," *Pharos Engineering Science Journal (PES),* vol. 1, pp. 39-50, 2025.

[65] M. Elkelawy, H. Alm-EldinBastawissi, E. El Shenawy, and M. M. Ouda, "A Greening the Diesel: Vegetable Oil Biodiesel Blends for Cleaner Emissions and Improved Direct Injection Diesel Engine performance," *Journal of Engineering Research*, vol. 8, p. 16, 2025.

[66] K. Willis, "Environmental economics and cost–benefit analysis," *The Routledge Companion to Environmental Planning*, pp. 382-393, 2019.

[67] M. Elkelawy, H. Bastawissi, A. Abdel-Rahman, A. Abou-elyazied, and S. El-malla, "The Impact of Incorporating Varying Proportions of Sugar Beet Waste on the Combustion Process and Emissions in Industrial Burner Fuelled with Conventional Diesel Fuel," in *Journal of Physics: Conference Series*, 2024, p. 012005.

[68] M. Elkelawy, A. Walaa, and M. M. Sayed, "Innovative Integration of Hydropower and Thermal Energy for Combined Heat and Power Production: A Comprehensive," *Pharos Engineering Science Journal (PES)*, vol. 1, p. 11, 2025.

[69] M. Elkelawy, H. A.-E. Bastawissi, M. O. Elsamadony, and A. Salem, "Investigation into the Impact of Ammonia Hydroxide on Performance and Emissions in Compression Ignition Engines Utilizing Diesel/Biodiesel Blends," *Journal of Engineering Research (ERJ)*, vol. 8, p. 21, 2024.

[70] H. Alm-EldinBastawissi, M. Elkelawy, M. O. Elsamadony, and M. Ghazaly, "Performance and Emissions Characteristics of Multi-Cylinder Direct Injection Diesel Engine Fuelled with Diesel/Biodiesel and Toluene Additives," *Journal of Engineering Research*, vol. 8, pp. 29-37, 2025.

[71] A. Zaidi, M. Ahmed, and A. Uddin, "Environmental Protection with Economic Gain: A Win-Win Situation," *Preprints*, 2019.

[72] A. Zentani, A. Almaktoof, and M. T. Kahn, "A comprehensive review of developments in electric vehicles fast charging technology," *Applied Sciences*, vol. 14, p. 4728, 2024.

[73] R. Baharom and M. H. Hayroman, "A Comprehensive Review on Advancements in Battery Charger Technologies for Electric Vehicles," in *2024 IEEE Industrial Electronics and Applications Conference (IEACon)*, 2024, pp. 190-195.

[74] A. Aksoz, B. Asal, E. Biçer, S. Oyucu, M. Gençtürk, and S. Golestan, "Advancing Electric Vehicle Infrastructure: A Review and Exploration of Battery-Assisted DC Fast Charging Stations," *Energies*, vol. 17, p. 3117, 2024.

[75] M. Elkelawy, E. El Shenawy, H. A.-E. Bastawissi, M. M. Shams, E. PV, D. Balasubramanian, *et al.*, "Predictive modeling and optimization of a waste cooking oil biodiesel/diesel powered CI engine: an RSM approach with central composite design," *Scientific Reports*, vol. 14, pp. 1-13, 2024.

[76] M. Elkelawy, H. A.-E. Bastawissi, E. El Shenawy, and M. Soliman, "A Quantitative Analysis of the Commercial-Additive Effects on Diesel Engine Combustion and Emissions Characteristics," *Pharos Engineering Science Journal (PES)*, vol. 1, p. 25, 2025.

[77] M. Elkelawy, W. M El-Ashmawy, and S. M. Ahmed, "State of the Art in Concentrated Solar Power: Latest Technological Advancements and Innovations in Efficiency and Energy Storage," *Pharos Engineering Science Journal*, vol. 1, pp. 17-28, 2025.

[78] M. Elkelawy, H. Bastawissi, E. A. E. Shenawy, and M. M. Ouda, "A Technical Survey on the Impact of Exhaust Gas Recirculation and Multifuel Blends on Diesel Engine Performance and Emission Characteristics," *Journal of Engineering Research*, vol. 8, p. 11, 2024.

[79] M. ELKELAWY, Z. A. ATTA, and H. SELEEM, "Technological Advances, Efficiency Optimization, and Challenges in Wind Power Plants: A Comprehensive Review," *Pharos Engineering Science Journal (PES)*, vol. 1, p. 10, 2025.

[80] Y. M. Prianka, A. Sharma, and C. Biswas, "Integration of Renewable Energy, Microgrids, and EV Charging Infrastructure: Challenges and Solutions," *Control Systems and Optimization Letters*, vol. 2, pp. 317-326, 2024.

[81] R. Damodharan and P. Sivakumar, "Improving Grid Stability and Power Quality in Advanced Technologies-Based Bidirectional EV Charging Stations: A Review," in *2024 4th International Conference on Sustainable Expert Systems (ICSES)*, 2024, pp. 139-148.

[82] A. A. Tavares, I. Fornasa, J. C. Cutipa-Luque, C. E. P. Saldias, L. F. B. Carbonera, and B. E. B. de Carvalho, "Power losses analysis and efficiency evaluation of an electric vehicle conversion," in *2018 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC)*, 2018, pp. 1-6.

[83] S. A. López-Freire, "Análisis de la eficiencia de los sistemas de conversión de energía eléctrica en vehículos eléctricos," *Horizon Nexus Journal*, vol. 1, pp. 68-80, 2023.

[84] R. Eviendy, M. Asy'Ari, Z. Sukra, and E. Peranginangin, "Carbon Emission and Economical Impact of Conversion Yamaha N-Max 150cc into Electric Motorcycle," in *IOP Conference Series: Earth and Environmental Science*, 2024, p. 012094.

[85] M. Kapetanović, A. Núñez, N. van Oort, and R. M. Goverde, "Energy use and greenhouse gas emissions of traction alternatives for regional railways," *Energy Conversion and Management*, vol. 303, p. 118202, 2024.

[86] A. M. Idris, N. A. Sasongko, and Y. D. Kuntjoro, "Energy conversion and conservation Technology in facing net zero-emission conditions and supporting national defense," *Trends in Renewable Energy*, vol. 8, pp. 49-66, 2022.

[87] Y. Lim, Z. Edel, E. Marker, S. Joung, and O. H. Kwon, "Data-Driven Battery Lifetime Model Calibration and Analysis for an Electric Vehicle Battery's Durability Performance," SAE Technical Paper 0148-7191, 2024.

[88] M. Dubarry, "Electric vehicle battery durability and reliability under electric utility grid operations," University of Central Florida. Electric Vehicle Transportation Center (EVTC)2017.

[89] G. Rizzo and F. A. Tiano, "Life cycle assessment study for different options of sustainable mobility, including vehicle conversion," *International Journal of Powertrains*, vol. 9, pp. 122-149, 2020.

[90] A. E. Esiri, J. M. Kwakye, D. E. Ekechukwu, and O. Benjamin , "Assessing the environmental footprint of the electric vehicle supply chain," 2023.

[91] X. Xue, X. Sun, H. Ma, J. Li, F. T. Hong, and S. Du, "Transportation decarbonization requires life cycle-based regulations: evidence from China's passenger vehicle sector," *Transportation Research Part D: Transport and Environment*, vol. 118, p. 103725, 2023.

[92] S. Teske, T. Pregger, S. Niklas, K. Nagrath, S. Talwar, S. Chatterjee, *et al.*, "Discussion, Conclusions, and Policy Recommendations," in *Achieving the Paris Climate Agreement Goals: Part 2: Science-based Target Setting for the Finance industry—Net-Zero Sectoral 1.5˚ C Pathways for Real Economy Sectors*, ed: Springer, 2022, pp. 353-365.