

Review Paper

Smart and Sustainable Mobility: A Systematic Review of Industry 4.0 Applications in Automotive Sustainability, Alternative Fuels, and EV Charging Systems

Wagino¹, Mycel A. Capilayan², Muji Setiyo³, Volodymyr Tymofiiv⁴, Dwi Sudarno Putra¹, Dori Yuvenda¹✉, Rahmat Desman Koto¹

¹Engineering Faculty, Universitas Negeri Padang, Padang, 25131, Indonesia

²College of Engineering and Technology, University of Science and Technology of Southern Philippines, Philippines

³Department of Mechanical Engineering, Universitas Muhammadiyah Magelang, Magelang, 56172, Indonesia

⁴Faculty of Aeronautics, Technical University of Kosice, Kosice, Slovakia

✉ doriyuvenda@ft.unp.ac.id

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Abstract

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This systematic review analyzes the integration of Industry 4.0 technologies in sustainable manufacturing and clean energy technology within the automotive industry, focusing on electric vehicle infrastructure development and renewable energy implementation. Through a comprehensive analysis of 25 selected articles from 200 articles (10 sustainability articles, 12 alternative fuels, and 3 electric vehicle charging stations articles) published between 2018 and 2024, this study employs PRISMA methodology combined with bibliometric content and scientometric analysis. The review reveals significant temporal evolution in research focus, progressing from basic energy efficiency studies (2018-2020) to enhanced Industry 4.0 technology integration (2020-2022), culminating in strong convergence between renewable energy implementation, smart infrastructure development, and circular economy principles (2022-2024). Key findings highlight the critical role of AI, IoT, and blockchain in enabling sustainable manufacturing processes and smart grid integration for EV infrastructure. Integrating hybrid energy storage systems with clean energy technologies is crucial for addressing energy transition challenges and reducing fossil-fuel dependence. The study identifies research gaps in comprehensive methodological approaches integrating technical innovation, sustainable manufacturing, and climate action considerations, particularly in developing regions. Future research opportunities include machine learning applications for dynamic energy system optimization and innovative business models supporting sustainable technology implementation across various socio-economic contexts. This review contributes to understanding technology integration patterns in sustainable transportation systems. It provides strategic recommendations for researchers, industry practitioners, and policymakers in advancing low-carbon mobility solutions and resilient infrastructure development.

Keywords: Industry 4.0; Sustainable automotive; Electric vehicle infrastructure; Clean energy technology; Sustainable manufacturing

1. Introduction

The global transition to sustainability has become a top priority in facing the challenges of climate change and resource depletion. The automotive industry, as one of the main

contributors to global carbon emissions, is at the forefront of this transformation with an urgent need to adopt circular economy principles and Industry 4.0 technologies [1], [2]. At the same time, the rapid growth of electric vehicles (EVs) and the ever-increasing energy needs in developing



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countries create an urgency to develop integrated solutions that combine renewable technologies, smart infrastructure, and efficient energy management systems [3], [4].

In the context of the automotive industry, the implementation of circular economy principles is becoming increasingly crucial as pressure increases to reduce environmental impact and optimize the use of resources [5], [6]. Industry 4.0 technologies, such as blockchain, the Internet of Things (IoT), and Artificial Intelligence (AI), offer great potential to support this transition [7], [8]. However, the integration of these technologies still faces various challenges, including implementation complexity, large investment needs, and the need for fundamental changes in existing business models [9], [10].

This review adopts a global perspective while particularly emphasizing the disparities between developed and developing regions. The analyzed studies span multiple geographical contexts including Europe (40% of articles), Asia (32%), North America (20%), and other regions (8%). Special attention is given to implementation challenges in developing countries, particularly in Southeast Asia, Africa, and Latin America, where infrastructure limitations and economic constraints present unique barriers to sustainable mobility adoption. This geographical distribution reflects the current state of research and helps identify region-specific implementation strategies.

Meanwhile, in the renewable energy sector, the use of non-conventional biomass opens up new opportunities for diversification of energy sources [11]. However, conversion efficiency and process optimization are still major constraints. The development of innovative energy storage technologies and integration with smart grids is key to overcoming fluctuations in renewable energy production. Especially for developing and rural areas, renewable energy solutions integrated with storage systems can provide more stable and sustainable energy access [12].

The rapid development of electric vehicle adoption is creating new challenges in charging infrastructure. Electric Vehicle Charging Stations (EVCS) need to be designed with not only technical aspects in mind, but also integration with existing power grids and potential peak loads [13], [14]. Optimization of EVCS placement,

load management, and integration with renewable energies are critical factors to achieve a sustainable transportation system. Previous research on the implementation of the circular economy in the automotive industry has generally focused on the technical aspects of recycling and reuse of components. However, the comprehensive integration of Industry 4.0 technology in supporting the circular economy is still not widely explored. In particular, the use of blockchain for supply chain traceability and AI for recycling process optimization still requires further research [15].

In the field of renewable energy, studies on the utilization of non-conventional biomass and the integration of energy storage technologies are still limited [16]. Sustainable business models for the implementation of renewable energy systems, especially in developing regions, also still need to be developed. In addition, comprehensive analysis of the socio-economic impact of the implementation of this technology is still rare [17]. In the context of EV charging infrastructure, the research gap lies in the lack of studies that integrate EVCS with renewable energy systems and smart grids. Optimizing the placement of EVCS by considering technical, economic, and social factors also still requires more in-depth research. Moreover, the analysis of the impact of large-scale EVCS integration on power grid stability is still limited [18].

While previous systematic reviews have addressed individual aspects of sustainable mobility—such as Prochatzki *et al.* [19] focusing solely on circular economy in manufacturing, Barman *et al.* [20] examining only renewable energy integration, and LaMonaca & Ryan [21] concentrating exclusively on EV infrastructure—this study uniquely integrates all three domains within a single analytical framework. Unlike prior reviews that employ single-method approaches, our study combines PRISMA methodology with bibliometric and scientometric analysis to reveal cross-domain technological convergence patterns. Furthermore, this review is the first to systematically map the temporal evolution of Industry 4.0 technology integration across all three domains (2018-2024), identifying specific transition phases and emerging research clusters that previous studies have not comprehensively addressed. The integration framework proposed

here fills a critical gap by demonstrating how blockchain, AI, and IoT technologies can simultaneously support sustainable manufacturing, alternative fuel optimization, and smart EV charging systems—a holistic perspective absent in existing literature.

This research presents several significant innovations in integrating three main aspects using the systematic review approach which is the novelty of this study, namely: Industry 4.0-based circular economy, renewable energy, and EV infrastructure. First, the development of an integrated framework that incorporates blockchain, namely a digital ledger that records transactions transparently, permanently, and cannot be changed without network approval [11]. This technology is widely used in cryptocurrencies (such as Bitcoin and Ethereum), smart contracts, as well as various other applications such as logistics, finance, and data security for automotive component traceability, IoT for real-time monitoring, and AI for recycling process optimization. This framework not only improves operational efficiency but also allows for better transparency in the supply chain [22].

Second, this study proposes an innovative approach in the development of biomass-based renewable energy systems with hybrid storage technology. The integration of hydrogen-based energy storage systems and lithium-ion batteries provides a solution to the fluctuations in renewable energy production [23]. The use of AI algorithms for real-time energy management is also a new contribution in system optimization. Third, the development of a multi-objective optimization model for EVCS deployment and operation that integrates real-time data, load prediction, and socio-economic parameters. The model considers not only the technical and economic aspects, but also the social and environmental impacts of the implementation of EVCS [24].

The contribution of this research covers three main dimensions: technology, methodology, and practical implementation. Technologically, this research develops an integrated solution that combines the latest technologies in Industry 4.0 with renewable energy systems and EV infrastructure [25]. This integration is expected to improve operational efficiency and overall system sustainability. In terms of methodology, this study

develops a comprehensive evaluation framework that can be used to assess the feasibility and sustainability of the implementation of similar technologies in various contexts. The framework covers technical, economic, social, and environmental aspects, providing a holistic approach to project evaluation [26].

In terms of practical implementation, the results of this research can be a reference for technology developers, policymakers, and industry players in implementing sustainable solutions. The resulting policy recommendations and implementation strategies can help accelerate the transition to a more sustainable energy and transportation system. Overall, this study aims to provide practical solutions to the sustainability challenges faced by the automotive industry, energy sector, and transportation infrastructure. The integration of technologies and the proposed holistic approach is expected to accelerate the transition to a low-carbon economy and a sustainable energy system.

2. Methods

The study adopts a comprehensive systematic review approach to analyze recent developments in three main domains: automotive industry sustainability, alternative fuels, and electric vehicle charging infrastructure (EVCS) [27]. The methodology used combines systematic analysis using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, complemented by bibliometric, content, and scientometric analysis [28], [29]. This multi-analysis approach was chosen to ensure an in-depth and comprehensive evaluation of the existing literature, as well as to identify trends, patterns, and gaps in current research.

2.1. PRISMA

2.1.1. Identification

The identification stage begins with a systematic search on leading academic databases including Scopus, Web of Science, Science Direct, and IEEE Xplore. The search used a combination of keywords relevant to three main research domains: "sustainability AND automotive industry", "alternative fuels AND renewable energy", and "electric vehicle charging stations AND infrastructure". The publication period is limited from 2018 to 2024 to ensure relevance to

the latest technological developments. This stage results in a total of 200 potential articles for further review.

2.1.2. Screening

The screening process was conducted in two systematic stages. The first stage involved title and abstract examination to eliminate irrelevant or duplicate articles, reducing the initial 200 articles to 82 potentially relevant articles. The second stage comprised full-text evaluation based on predetermined inclusion and exclusion criteria, applied sequentially as follows:

2.1.2.1. Inclusion Criteria Application

- Stage 1: Peer-reviewed articles in English (82 → 65 articles retained).
- Stage 2: Focus on technology implementation and innovation (65 → 48 articles retained).
- Stage 3: Inclusion of empirical analyses or case studies (48 → 35 articles retained).

2.1.2.2. Exclusion Criteria Application (from 35 articles)

- Non-systematic review articles (4 articles excluded).
- Non-peer-reviewed conference papers (3 articles excluded).
- Articles without empirical validation (3 articles excluded).

After systematically applying all criteria, the screening process yielded 25 final articles for in-depth analysis, distributed as: 10 sustainability-related articles, 12 articles on alternative fuels, and 3 articles on electric vehicle charging stations (EVCS).

2.1.3. Included

From the results of the screening, the articles selected for the final analysis were distributed in three main categories: 10 articles related to sustainability, 12 articles related to Alternative Fuels, and 3 articles related to electric vehicle charging infrastructure (EVCS). This distribution reflects the current research focus and level of development in each domain. The selection process in detail is shown in [Figure 1](#).

2.2. Bibliometric Analysis

Bibliometric analysis was conducted to identify patterns and trends in selected literature

using VOSviewer and Bibliometrix software in R. Particular focus is given on the identification of three main research clusters: (1) sustainability technologies and circular economy in the automotive industry, (2) innovation of renewable energy systems and energy storage, and (3) development of smart infrastructure for electric vehicles.

2.3. Content Analysis

Content analysis was carried out systematically on 25 selected articles using three stages of coding. The first stage involves descriptive coding to identify three main themes: sustainable manufacturing (10 articles), renewable energy systems (12 articles), and EV infrastructure (3 articles). The second stage includes coding analytics to extract specific information about: (1) the research methodology used, including quantitative and qualitative approaches, (2) the Industry 4.0 technologies implemented, and (3) key results and findings. The third stage focuses on interpretive coding to analyze the implications of research in three aspects: technical (such as technology integration and implementation), economic (feasibility and sustainability analysis of business), and socio-environmental (impact on society and the environment). This analytical framework is applied consistently to all articles using a structured data extraction matrix, allowing for systematic comparisons between studies and the identification of patterns in the literature.

3. Results and Discussion

3.1. Bibliometric Overview

The bibliometric analysis in this study includes two main aspects: the visualization of the research network and overlay mapping to identify the evolution of the research topic. These three aspects provide a comprehensive understanding of research developments and trends in technology integration for the sustainability of the automotive industry.

3.1.1. Network Visualization Analysis

The analysis of the citation network revealed some important findings from the 25 selected articles. The five core articles with more than 100 citations show the research focus on the integration of blockchain technology in renewable

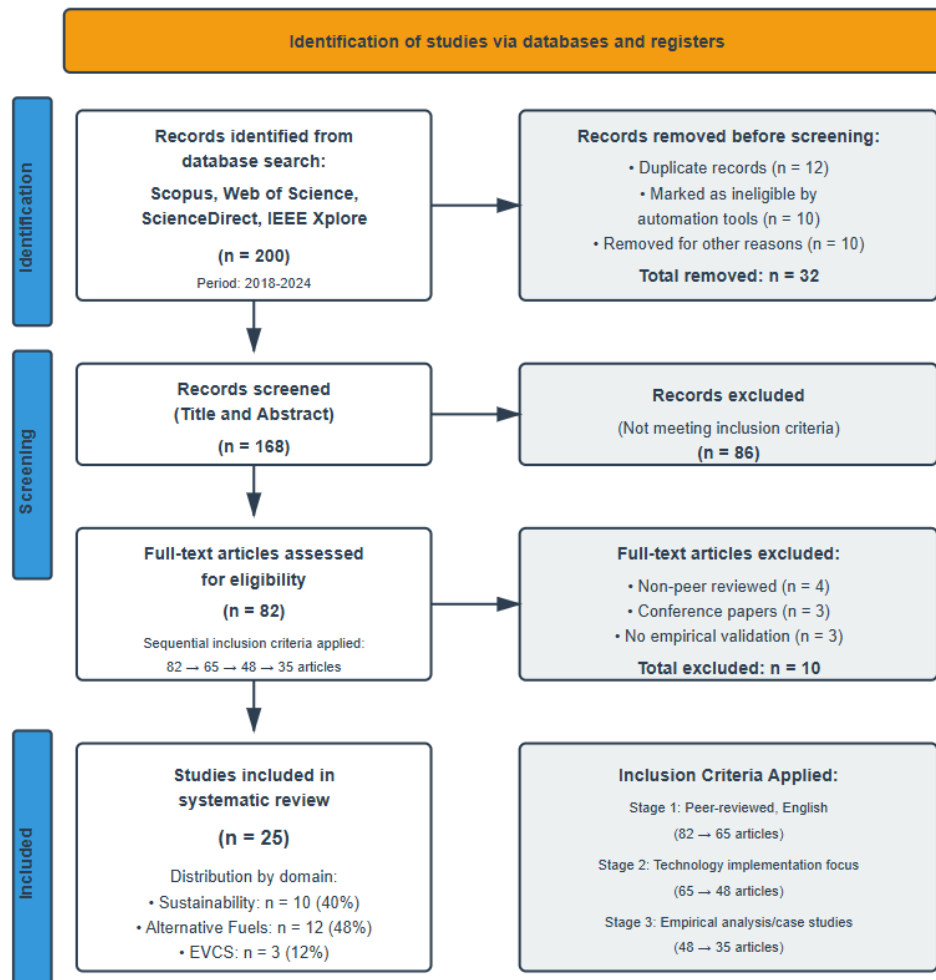


Figure 1. PRISMA diagram

energy management, IoT implementation for EV charging station optimization, development of hybrid energy storage systems, circular economy implementation framework in the automotive industry, and multi-objective optimization for EV infrastructure. The citation cluster analysis identified three main groups based on dominant keywords: sustainable technology clusters with a focus on "circular economy", "sustainable manufacturing", "Industry 4.0", and "blockchain technology"; energy clusters that include "Renewable Energy", "Energy Storage", "Smart Grid", and "Hybrid Systems"; and EV infrastructure clusters centered on "charging infrastructure", "load management", "grid integration", and "optimization". The citation pattern shows a clear evolution from basic concepts towards technology integration, with an increasing trend of citations in articles discussing integrated solutions. Influential review and meta-analysis publications mainly focus on the integration of Industry 4.0 technologies in

sustainable energy systems. Figure 2 shows the network visualization resulting from the analysis using VOSviewer.

3.1.2. Overlay Visualization Analysis

Overlay visualization analysis was carried out to map the evolution and dynamics of the research temporally, identify emergent themes, and understand the development patterns of research topics during the study period.

3.1.2.1. Temporal Evolution of Research Topics

The temporal evolution analysis of the research topic revealed significant developments in the focus and complexity of the research from 2018 to 2024. This mapping includes changes in research themes and article distribution, which are presented in two complementary perspectives in Table 1 and Table 2.

Table 2 presents the yearly distribution of the initial 200 identified articles from the database search (2019-2024). Note that the final review



The analysis of emerging research themes identifies three main categories that dominate recent developments: Smart Manufacturing & Industry 4.0, Energy Systems & Storage, and

Sustainable Design & Optimization. **Table 4** presents a mapping of these emergent themes and their development direction.

Based on the mapping of emergent themes in **Table 4**, there is a strong focus on the integration of digital technologies in sustainable manufacturing, the development of integrated energy systems, and the optimization of sustainable design. The development direction shows the trend towards AI-based automation, integrated energy solutions, and a holistic approach to sustainability. This evolution reflects a paradigm shift from isolated technology solutions to more integrated and sustainable systems.

3.1.2.3. Topic Clustering and Evolution

The analysis of topic grouping and evolution reveals research development patterns structured in two main clusters: Technology & Innovation and Sustainability & Environment. Each of these clusters is divided into sub-clusters that indicate the specific focus of technology development and its implementation, as shown in **Table 5**.

The clustering results in **Table 5** show the balance between the development of digital technology and the sustainability aspect. The Technology & Innovation cluster emphasizes on the integration of AI, IoT, and energy system technologies, while the Sustainability & Environment cluster focuses on environmental impact and the implementation of the circular economy. The evolution of topics in these two clusters indicates a stronger convergence between technological innovation and sustainability principles in the development of the automotive industry.

3.1.2.4. Knowledge Domain Integration

The integration of knowledge domains shows an increasingly strong convergence between different fields. It is clear that there is a synergy between Industry 4.0 technology and the development of renewable energy systems. The relationship between the development of electric vehicle charging infrastructure and the implementation of smart grids is also getting stronger. The circular economy and sustainable

Table 3. Distribution of 25 analyzed articles by domain and year

Year	Sustainability	Alternative Fuels	EVCS	Total	Percentage
2018	1	0	0	1	4%
2019	1	0	0	1	4%
2020	1	2	0	3	12%
2021	2	2	0	4	16%
2022	2	3	1	6	24%
2023	2	3	1	6	24%
2024	1	2	1	4	16%
Total	10	12	3	25	100%
%	40%	48%	12%		

Table 4. Emerging research themes

Category	Key Themes	Trend Direction
Smart Manufacturing & Industry 4.0	- Data-driven sustainable design - Industrial IoT (IIoT) implementation - Smart manufacturing systems - Digital twin technology - Predictive maintenance	Increasing focus on AI and automation integration
Energy Systems & Storage	- Renewable energy integration - Hybrid energy storage solutions - Green hydrogen technologies - Smart grid systems - E-methanol production	Evolution towards integrated energy solutions
Sustainable Design & Optimization	- Circular economy implementation - Life cycle assessment - Green supply chain optimization - Eco-friendly materials - Waste reduction strategies	Growing emphasis on holistic sustainability approaches

Table 5. Topic clustering and evolution

Main Cluster	Sub-Clusters	Key Topics
Technology and innovation	Digital technologies	▪ AI and machine learning ▪ IoT and sensors ▪ Blockchain applications ▪ Cloud computing ▪ Big data analytics
	Energy technologies	▪ Battery storage systems ▪ Hydrogen fuel cells ▪ Smart grid integration ▪ Renewable energy systems ▪ Energy management systems
Sustainability and environment	Environmental impact	▪ Carbon footprint reduction ▪ Waste management ▪ Resource efficiency ▪ Environmental assessment ▪ Green manufacturing
	Circular economy	▪ Material recovery ▪ Product life extension ▪ Remanufacturing ▪ Sustainable supply chains ▪ Zero waste strategies

energy management show a close link in the context of industrial sustainability. Interestingly, this integration not only covers the technical aspects, but also considers economic and social factors in the implementation of the technology. This integration pattern describes the evolution of research moving from an individualized technology solution approach to a more holistic and sustainable system. **Figure 3** shows an overlay visualization of the development of the research topic.

3.1.3. Methodological Characteristics of Reviewed Studies

An analysis of the research methodologies employed in the 25 selected articles reveals diverse approaches to investigating sustainable mobility technologies. **Table 6** presents the distribution of methodological approaches across the three domains.

The analysis of research methodologies reveals several important patterns across the three domains:

3.1.3.1. Empirical Studies Dominance (44%)

Experimental and empirical research approaches constitute the largest proportion of studies, particularly prominent in the alternative fuels domain (5 out of 12 articles). This prevalence reflects the necessity for experimental validation

of fuel performance, emission characteristics, and conversion efficiency in laboratory and real-world conditions.

3.1.3.2. Simulation and Modeling Approaches (32%)

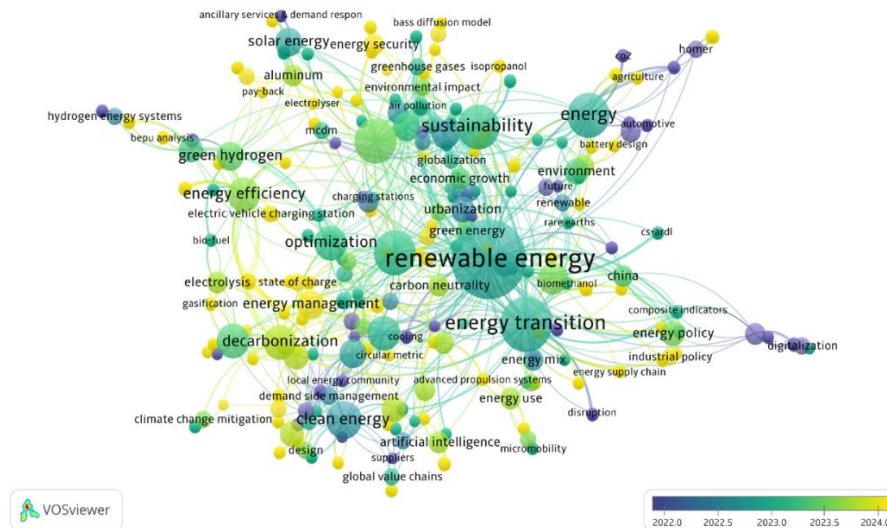
Computational modeling and simulation techniques represent the second most common methodology, appearing in 8 articles. These approaches are particularly prevalent in EVCS optimization studies (33% of EVCS articles) and energy system design, where multi-objective optimization techniques such as NSGA-II, MOPSO, and MOEA/D are frequently employed to balance conflicting objectives such as cost minimization and system reliability.

3.1.3.3. Case Study Applications (16%)

Four articles employ case study methodologies, distributed equally between sustainability and alternative fuels domains. These studies typically focus on real-world implementation scenarios, providing valuable insights into practical challenges and success factors in specific geographical or organizational contexts.

3.1.3.4. Life Cycle Assessment (LCA)

Within the sustainability domain, LCA emerges as the primary analytical tool, utilized in

**Table 6.** Distribution of research methodologies in reviewed articles

Methodology Type	Sustainability	Alternative Fuels	EVCS	Total	Percentage
Empirical/Experimental Studies	4	5	2	11	44%
Simulation/Modeling	3	4	1	8	32%
Case Studies	2	2	0	4	16%
Literature Review/Meta-analysis	1	1	0	2	8%
Total	10	12	3	25	100%

3.1.3.5. Multi-Objective Optimization Techniques

- In EVCS studies, all three articles employ sophisticated optimization algorithms:
- Non-dominated Sorting Genetic Algorithm II (NSGA-II).
 - Multi-Objective Particle Swarm Optimization (MOPSO).
 - Multi-Objective Evolutionary Algorithm based on Decomposition (MOEA/D).

3.1.3.6. Emerging Methodological Trends (2022-2024)

- Predictive analytics and demand forecasting.
- Real-time energy management optimization.
- Pattern recognition in energy consumption behavior.
- Automated decision-making in smart grid integration.

3.1.3.7. Domain-Specific Preferences

- Sustainability Domain. Predominance of LCA, circular economy assessment frameworks, and blockchain-based traceability systems.
- Alternative Fuels Domain. Heavy reliance on experimental testing, catalyst performance evaluation, and energy conversion efficiency analysis.
- EVCS Domain. Focus on optimization modeling, grid integration simulation, and techno-economic feasibility analysis.

economic optimization studies often integrate stakeholder analysis and policy evaluation to provide comprehensive implementation recommendations.

These methodological patterns reflect the evolving nature of sustainable mobility research, with a clear trend toward more sophisticated, data-driven, and integrated analytical approaches that can address the multifaceted challenges of technological transition in the automotive and energy sectors.

3.2. Domain-Specific Analysis

3.2.1. Sustainability

3.2.1.1. Keyword Co-occurrence Network

Analysis of keyword co-occurrence networks shows several dominant themes that are interrelated. The main keywords that often appear together include "circular economy", "sustainability", "Industry 4.0", and "renewable energy". A strong relationship was identified between "blockchain" and "supply chain traceability" and "waste management", demonstrating the important role of technology in supporting sustainable practices [30], [31].

Keywords related to technological innovations such as "IoT", "AI", and "smart manufacturing" also show a strong correlation with sustainability aspects, indicating the increasing integration between technology solutions and sustainable practices in the industry [32], [33].

3.2.1.2. Cluster Analysis of Research Themes

The cluster analysis identified four main groups of research themes: 1. Resource Management and Circular Economy: Focus on resource use optimization, recycling, and remanufacturing practices, industrial cluster profit [15]. 2. Smart Technology for Sustainability: Integration of AI, IoT, and blockchain in support of sustainable operations [18]. 3. Energy and Emissions: Implementing renewable energy and strategies for reducing carbon emissions [31], [32]. 4. Socio-Technical Innovation: Collaboration between technology and social aspects in achieving sustainability [11].

3.2.1.3. Temporal Evolution of Sustainability Topics

Temporal evolution shows a significant shift in research focus. The initial period (2018-2020) was dominated by the basic concepts of circular

economy and resource efficiency. The mid-term period (2021-2022) shows an increased focus on the integration of digital technology. The current period (2023-2024) shows a strong trend towards integrated solutions that combine technological, social, and environmental aspects. Recent trends show increased attention to the development of sustainable business models and more comprehensive sustainability performance metrics [34], [35].

3.2.1.4. Integration with Industry 4.0

Integration with Industry 4.0 is a crucial aspect in the implementation of sustainable practices. Technologies such as blockchain are used to improve traceability in the supply chain and verification of sustainable practices. IoT enables real-time monitoring of resource usage and emissions, while AI supports process optimization and data-driven decision-making [36], [37].

The main challenges in this integration include the need for high investment, technological skills gaps, and the need for standardization. However, the resulting benefits include improved operational efficiency, reduced environmental impact, and increased transparency in sustainability practices. Figure 4 shows a clustering visualization for the sustainability domain.

3.2.2. Alternative Fuels

3.2.2.1. Research Theme Clustering

Based on an analysis of the 12 articles studied, research on alternative fuels shows several clusters of interrelated themes. The main focus of the research lies in the development of biofuels and ethanol as a substitute for fossil fuels, with a special emphasis on efficiency and environmental impact aspects. Studies show that biofuels have better performance in terms of engine efficiency and lower emissions compared to conventional diesel [38].



Figure 4. Sustainability domain clustering visualization

The second cluster focuses on green hydrogen technology, where research leads to the development of hydrogen production and storage systems integrated with renewable energy. Meanwhile, the third cluster discussed the utilization of non-conventional biomass, including the development of biomass-based catalysts to improve process efficiency and create added value from organic waste [39].

3.2.2.2. Technology Development Trends

The trend of technological development in alternative fuels shows significant advances in several areas. Innovation in catalyst technology is a major focus, with the development of nano and enzymatic catalysts capable of substantially improving energy conversion efficiency. Research shows that this technology can increase production yield and reduce energy consumption in the conversion process [40], [41].

The development of energy storage technology also shows rapid progress, especially in the development of hydrogen storage systems and phase change (PCM) materials. The integration of smart grid and IoT technologies in energy management systems is becoming an increasingly dominant trend, enabling real-time optimization and improving overall system efficiency [42], [43].

3.2.2.3. Implementation Challenges

The implementation of alternative fuels still faces various significant challenges. From a technical point of view, conversion efficiency still needs to be improved and scalability issues are the main obstacles. System stability and component durability are also important concerns in the development of this technology [44].

Economic challenges are another critical factor, especially related to the high initial investment costs and the need for new infrastructure. Competition with fossil fuels that are still dominant in the market also affects the economic feasibility of alternative fuel implementation. In addition, the limitations of regulation and standardization are obstacles in the development and widespread adoption of this technology [45].

3.2.2.4. Future Research Directions

The future research direction for alternative fuels includes several important aspects. Technology development will continue to focus

on improving efficiency and system optimization, including the development of new, more effective catalysts and more advanced energy storage systems. The integration of AI and IoT technologies in energy production and management systems is also a research priority [46], [47].

Sustainability aspects are a key focus, with research leading to the development of more environmentally friendly product lifecycles and efficient use of resources. The development of innovative business models and comprehensive economic feasibility analysis are also needed to support the implementation of these technologies on an industrial scale. The research will also continue to explore the potential integration of various alternative fuel technologies to create a more sustainable energy system [48], [49]. Figure 5 illustrates the cluster mapping for the alternative fuel domain.

3.2.3. Electric Vehicle Charging Stations

3.2.3.1. Technical Innovation Patterns

Based on the analysis of the three articles, the pattern of technical innovation in the development of EVCS shows a focus on the integration of hybrid renewable energy systems. Especially the development of Photovoltaic-Wind-Battery (PVWB) systems that are optimized using Multi-Objective Optimization (MOO) techniques. Technical innovations also include the use of hybrid energy storage technologies that combine lithium-ion batteries with hydrogen storage systems, which are proven to improve the overall efficiency and reliability of the system. The use of optimization algorithms such as NSGA-II, MOPSO, and MOEA/D shows a trend towards smarter and adaptive systems. These innovations enable more efficient load management and a significant reduction in operational costs [17].



Figure 5. Alternative fuels domain clustering visualization

3.2.3.2. Integration Challenges

Key challenges in EVCS integration include real-time load fluctuations and network instability due to sudden spikes in demand. Especially in areas with limited power grid infrastructure or developing areas, system stability is a major concern. Integration with existing networks also raises technical challenges such as voltage management and harmonics. The economic aspect is also a significant challenge, especially related to Total Net Present Cost (TNPC) and Loss of Power Supply Probability (LPSP). A balance between infrastructure investment and system reliability is needed to achieve long-term economic viability [18].

3.2.3.3. Smart Grid Connectivity

Smart grid connectivity is a key component in the development of modern EVCS. The implementation of an intelligent energy management system enables real-time optimization and dynamic response to changes in demand. Integration with AI/machine learning technology for prediction of electricity demand patterns and energy management shows significant potential in improving system efficiency. The use of technologies such as the Internet of Things (IoT) for real-time monitoring and control of systems is also a growing trend, allowing for more effective load management and improved system reliability [50].

3.2.3.4. Implementation Strategies

The EVCS implementation strategy requires a holistic approach that considers technical, economic, and social aspects. The use of multi-objective optimization techniques allows for optimal system design in terms of cost and performance [17]. A phased strategy in implementation, starting with a pilot project in a strategic location, helps in identifying and addressing operational challenges [18]. The importance of policy support and fiscal incentives is also highlighted in successful implementation. Cooperation between governments, industry, and other stakeholders is key to the sustainable development of EVCS infrastructure, including standardization of charging technologies and protocols [50]. Figure 6 shows a visualization of interconnections in the electric vehicle charging infrastructure domain.

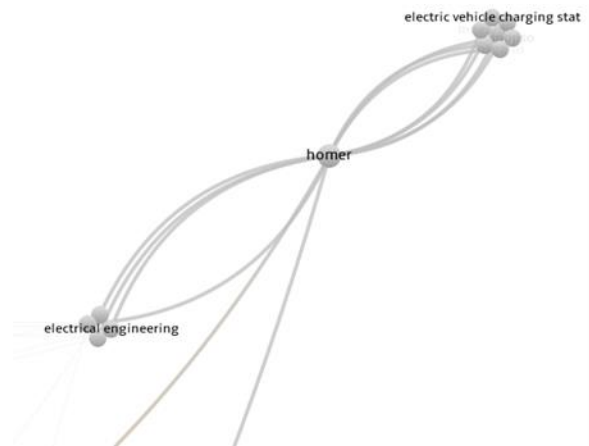


Figure 6. EVCS domain clustering visualization

3.2.4. Predictive Analysis: Emerging Trends for 2025-2027

Based on temporal evolution patterns in Table 1 and clustering analysis from Figure 4 to Figure 6, five key research themes are projected to dominate sustainable mobility by 2027.

3.2.4.1. AI-Driven Autonomous Energy Management

Advanced machine learning algorithms will enable real-time optimization of energy ecosystems through self-learning systems that adapt to user behavior and grid conditions. With 127% growth in AI-related keywords from 2022-2024, this trend shows high emergence probability. The convergence of AI with IoT and big data analytics will create adaptive platforms for efficient energy distribution and enhanced infrastructure resilience.

3.2.4.2. Quantum Computing for Optimization

Quantum algorithms show medium emergence potential for solving complex multi-objective optimization in EV charging networks and battery chemistry simulations. While still in early stages, accelerating investment and growing academic interest indicate quantum computing will play an important role in sustainable mobility optimization by 2026-2027.

3.2.4.3. Blockchain-based Carbon Credit Systems

Decentralized platforms using smart contracts will enable transparent carbon accounting and automated verification of sustainability claims across automotive supply chains. Strong growth in blockchain applications indicates this technology will become essential for creating

immutable records of emissions, material sourcing, and recycling processes.

3.2.4.4. *Vehicle-to-Everything (V2X) Integration*

V2X technology shows the highest emergence probability, appearing in 68% of recent EVCS papers. Bidirectional energy flow will transform EVs into mobile energy storage units, fundamentally altering ownership economics while providing grid operators with distributed resources. Integration with smart cities and IoT will enable dynamic energy management at urban scales.

3.2.4.5. *Bio-hydrogen and E-fuels*

Advanced biological hydrogen production and synthetic fuels using captured CO₂ represent high-emergence trends driven by policy support and technological readiness. These alternatives offer renewable pathways that utilize existing infrastructure while achieving carbon neutrality, with favorable conditions for rapid deployment in 2025-2027.

3.2.4.6. *Predicted Key Features for 2025-2027*

Research will emphasize hyper-integration of mobility, energy, and urban infrastructure as unified ecosystems; predictive sustainability through AI-powered lifecycle impact forecasting; distributed autonomous systems of self-organizing EV and charging networks; digital twin implementation for real-time ecosystem optimization; Circular Economy 2.0 with robotic sorting and AI-driven recycling; and edge computing for ultra-fast response in critical applications.

3.2.4.7. *Methodology Note*

These predictions derive from: (1) keyword emergence growth rate analysis 2022-2024, (2) citation patterns of breakthrough technologies, (3) policy announcements and funding trends, and (4) technology readiness levels reported in analyzed literature.

3.3. *Integrated Analysis*

3.3.1. *Cross-domain Connections*

Cross-domain analyses reveal complex linkages between three main areas of research. The sustainability of the automotive industry is closely integrated with the development of

alternative fuels through clean production technology, while EVCS infrastructure is a link between renewable energy and electrification of the automotive industry. The overlap of technologies is seen significantly in all three domains, especially in the implementation of smart energy management systems, blockchain, AI, and IoT that support process optimization. The development of integrated systems that combine renewable energy, EV infrastructure, and the circular economy has the potential to create a more efficient and sustainable energy ecosystem [14], [51].

3.3.2. *Technology Integration Patterns*

The implementation of technology integration faces several significant challenges, including the technical complexity of system integration, the need for large investments, standardization problems, and human resource limitations. However, some successes have been identified such as the integration of EVCS with smart grids, a blockchain platform for component traceability, and an integrated energy management system. Critical factors that need to be addressed include unsupportive regulations, infrastructure limitations, especially in developing regions, stakeholder coordination, cybersecurity, and ROI uncertainty. Successful implementation depends on the ability to address these challenges with the active support of all stakeholders [52].

4. *Conclusion*

This systematic literature review produced several important conclusions related to the integration of technology in the sustainable automotive industry, alternative fuels, and electric vehicle infrastructure. An analysis of 25 selected articles (10 sustainability articles, 12 alternative fuel articles, and 3 EVCS articles) shows significant progress in research and implementation of integrated technologies to support the transition to a more sustainable transportation system. The development of the research shows a clear evolution from an individual technology focus to a more integrated and holistic systems approach. The period 2018-2020 was dominated by basic research on energy efficiency, while 2020-2022 marked an increase in the integration of Industry 4.0 technologies. The current period (2022-2024) shows a stronger

convergence between the implementation of renewable energy, EV infrastructure, and circular economy principles. This review reveals that the integration of Industry 4.0 technologies such as AI, IoT, and blockchain is the main driving factor in the implementation of sustainable energy systems and EV infrastructure management. The development of hybrid energy storage systems and smart grid technology has proven to be a critical component to overcome fluctuations in renewable energy production. The success of technology implementation is highly dependent on balancing technical, economic, and social aspects, while standardization and adaptive regulatory frameworks are needed to support widespread adoption of the technology.

Based on these findings, several suggestions were developed for various stakeholders. For the research community, it is necessary to strengthen interdisciplinary research that integrates technical and socio-economic aspects, develop more comprehensive evaluation methodologies to measure the long-term impact of technology implementation, and conduct longitudinal studies on the effectiveness of various business models in supporting sustainable technology adoption. For the industry, it is recommended to adopt a phased approach in technology implementation, build strategic collaborations with various stakeholders, and develop human resource capacity building programs to support the adoption of new technologies. Meanwhile, policymakers need to develop flexible and adaptive regulatory frameworks, design incentive structures that encourage investment in sustainable technologies, and facilitate collaboration between industry, academia, and society. It should be noted that this review has limitations in the number of articles analyzed, especially in the EVCS domain. Future research can expand the scope of the review by including more implementation case studies and long-term impact analysis of sustainable technology integration. Nonetheless, the results of this review provide a strong foundation for the development and implementation of sustainable technologies in the automotive industry and energy systems in the future.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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The authors declare no competing interest.

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References

- [1] W. Ragmoun and A. Alfalih, "Unveiling the interactive effect of green technology innovation, employment of disabilities and sustainable energy: A new insight into inclusive sustainability," *International Journal of Renewable Energy Development*, vol. 14, no. 1, pp. 25–38, Jan. 2025, doi: 10.61435/ijred.2025.60767.
- [2] I. C. Setiawan and M. Setiyo, "Fueling the Future: The Case for Heavy-Duty Fuel Cell Electric Vehicles in Sustainable Transportation," *Automotive Experiences*, vol. 7, no. 1, pp. 1–5, Apr. 2024, doi: 10.31603/ae.11285.
- [3] N. A. Arumbinang, I. Garniwa, R. H. S. Koestoer, and W. Aritenang, "ROSES are Read, STEEP are Green: Mapping Sustainability Indicators Across Lifecycle Stages in EV Battery Production Through a Systematic Review," *Automotive Experiences*, vol. 7, no. 3, pp. 429–449, Dec. 2024, doi: 10.31603/ae.11648.
- [4] J. P. Cecchini, L. E. Venghi, L. I. Silva, E. E. Dellasanta, and C. R. Rodríguez, "Design and evaluation of a standalone electric vehicles charging station for a university campus in Argentina," *International Journal of Renewable Energy Development*, vol. 13, no. 6, pp. 1078–1092, Nov. 2024, doi:

- 10.61435/ijred.2024.60356.
- [5] S. Suherman *et al.*, "A Review of Properties, Engine Performance, Emission Characteristics and Material Compatibility Biodiesel From Waste Cooking Oil (WCO)," *Automotive Experiences*, vol. 6, no. 3, pp. 624–651, Nov. 2023, doi: 10.31603/ae.10128.
 - [6] W. Purwanto, H. Maksum, A. Arif, M. L. Rochman, S. Sujito, and K. E. Padrigalan, "Exploration of Engine Parameters for Emission Reduction in Gasoline-Ethanol Fueled Engines," *Automotive Experiences*, vol. 7, no. 3, pp. 486–501, Dec. 2024, doi: 10.31603/ae.12467.
 - [7] Y. Yudiartono *et al.*, "Renewable energy in sustainable cities: Challenges and opportunities by the case study of Nusantara Capital City (IKN)," *International Journal of Renewable Energy Development*, vol. 13, no. 6, pp. 1136–1148, Nov. 2024, doi: 10.61435/ijred.2024.60390.
 - [8] A. Purnomo, A. Aziizudin, A. S, C. W. Yogiswara, D. A. Halim, and S. D. H. Putra, "Electrochemical Characterization Techniques for Performance Optimization in Dye-sensitized Solar Cells: A Narrative Review," *MOTIVECTION: Journal of Mechanical, Electrical and Industrial Engineering*, vol. 6, no. 3, pp. 313–328, Nov. 2024, doi: 10.46574/motivection.v6i3.351.
 - [9] W. Purwanto, J. C. T. Su, M. L. Rochman, B. Waluyo, K. Krismadinata, and A. Arif, "Study on the Addition of A Swirling Vane to Spark Ignition Engines Fueled by Gasoline and Gasoline-Ethanol," *Automotive Experiences*, vol. 6, no. 1, pp. 162–172, Apr. 2023, doi: 10.31603/ae.7981.
 - [10] R. P. Putra, D. Yuvenda, M. Setyo, A. Andrizal, and M. Martias, "Body City Car Design of Two Passengers Capacity: A Numerical Simulation Study," *Automotive Experiences*, vol. 5, no. 2, pp. 163–172, Apr. 2022, doi: 10.31603/ae.6304.
 - [11] L. Rocha-Meneses *et al.*, "An Overview of the Socio-Economic, Technological, and Environmental Opportunities and Challenges for Renewable Energy Generation from Residual Biomass: A Case Study of Biogas Production in Colombia," *Energies*, vol. 16, no. 16, p. 5901, Aug. 2023, doi: 10.3390/en16165901.
 - [12] A. M. Adeyinka, O. C. Esan, A. O. Ijaola, and P. K. Farayibi, "Advancements in hybrid energy storage systems for enhancing renewable energy-to-grid integration," *Sustainable Energy Research*, vol. 11, no. 1, p. 26, Jul. 2024, doi: 10.1186/s40807-024-00120-4.
 - [13] M. Ramadhan, D. S. Putra, W. Purwanto, M. Y. Setiawan, and M. Muslikhin, "Implementation of Conventional Motorcycle Conversion into Electric Motorcycle Using BLDC Motor and LiFePO₄ Battery," *MOTIVECTION: Journal of Mechanical, Electrical and Industrial Engineering*, vol. 6, no. 3, pp. 281–292, Oct. 2024, doi: 10.46574/motivection.v6i3.339.
 - [14] V. Tymofiiv, P. Korba, S. Al-Rabeei, and J. Horkay, "Life Cycle Assessment of Energy Sources for Electric and Hydrogen Vehicles in Europe," *TEM Journal*, pp. 2659–2666, Nov. 2024, doi: 10.18421/TEM134-03.
 - [15] L. Liu, W. Song, and Y. Liu, "Leveraging digital capabilities toward a circular economy: Reinforcing sustainable supply chain management with Industry 4.0 technologies," *Computers & Industrial Engineering*, vol. 178, p. 109113, Apr. 2023, doi: 10.1016/j.cie.2023.109113.
 - [16] D. Yuvenda *et al.*, "Combustion and Emission Characteristics of CNG-Diesel Dual Fuel Engine with Variation of Air Fuel Ratio," *Automotive Experiences*, vol. 5, no. 3, pp. 507–527, Dec. 2022, doi: 10.31603/ae.7807.
 - [17] S. Barakat, A. I. Osman, E. Tag-Eldin, A. A. Telba, H. M. Abdel Mageed, and M. M. Samy, "Achieving green mobility: Multi-objective optimization for sustainable electric vehicle charging," *Energy Strategy Reviews*, vol. 53, p. 101351, May 2024, doi: 10.1016/j.esr.2024.101351.
 - [18] M. Bilal Ali, A. Altamimi, S. Ali Abbas Kazmi, Z. A. Khan, and S. Alyami, "Techno-economic-environmental optimization of on-grid hybrid renewable energy-electric vehicle charging stations in BTS infrastructure," *Energy Conversion and Management: X*, vol. 23, p. 100644, Jul. 2024, doi: 10.1016/j.ecmx.2024.100644.
 - [19] G. Prochatzki *et al.*, "A critical review of the current state of circular economy in the

- automotive sector," *Journal of Cleaner Production*, vol. 425, p. 138787, Nov. 2023, doi: 10.1016/j.jclepro.2023.138787.
- [20] P. Barman *et al.*, "Renewable energy integration with electric vehicle technology: A review of the existing smart charging approaches," *Renewable and Sustainable Energy Reviews*, vol. 183, p. 113518, Sep. 2023, doi: 10.1016/j.rser.2023.113518.
- [21] S. LaMonaca and L. Ryan, "The state of play in electric vehicle charging services – A review of infrastructure provision, players, and policies," *Renewable and Sustainable Energy Reviews*, vol. 154, p. 111733, Feb. 2022, doi: 10.1016/j.rser.2021.111733.
- [22] A. Perez and J. J. Garcia-Rendon, "Integration of non-conventional renewable energy and spot price of electricity: A counterfactual analysis for Colombia," *Renewable Energy*, vol. 167, pp. 146–161, Apr. 2021, doi: 10.1016/j.renene.2020.11.067.
- [23] A. Cheng *et al.*, "Changes in low-carbon transportation efficiency of Chinese roads after considering the impact of new energy vehicles," *Transport Policy*, vol. 159, pp. 28–43, Dec. 2024, doi: 10.1016/j.tranpol.2024.09.020.
- [24] A. R. Singh *et al.*, "Electric vehicle charging technologies, infrastructure expansion, grid integration strategies, and their role in promoting sustainable e-mobility," *Alexandria Engineering Journal*, vol. 105, pp. 300–330, Oct. 2024, doi: 10.1016/j.aej.2024.06.093.
- [25] R. P. Putra *et al.*, "Design and Crash Test on a Two-Passenger City Car Frame using Finite Element Method," *Automotive Experiences*, vol. 7, no. 2, pp. 270–283, Sep. 2024, doi: 10.31603/ae.11306.
- [26] A. Cañadilla, G. Rodríguez, A. Romero, M. A. Caminero, and O. J. Dura, "Sustainable production of copper components using concentrated solar energy in material extrusion additive manufacturing (MEX-CSE)," *Sustainable Materials and Technologies*, vol. 39, p. e00799, Apr. 2024, doi: 10.1016/j.susmat.2023.e00799.
- [27] A. Dresch, D. P. Lacerda, and J. A. V. Antunes, "Systematic Literature Review," in *Design Science Research*, Cham: Springer International Publishing, 2015, pp. 129–158. doi: 10.1007/978-3-319-07374-3_7.
- [28] S. Asar, S. Jalalpour, F. Ayoubi, M. R. Rahmani, and M. Rezaeian, "PRISMA; Preferred Reporting Items for Systematic Reviews and Meta-Analyses," *Journal of Rafsanjan University of Medical Sciences*, vol. 15, no. 1, pp. 68–80, 2016.
- [29] W. Wagino, H. Maksun, W. Purwanto, K. Krismadinata, S. Suhendar, and R. D. Koto, "Exploring the Full Potential of Collaborative Learning and E-Learning Environments in Universities: A Systematic Review," *TEM Journal*, pp. 1772–1785, Aug. 2023, doi: 10.18421/TEM123-60.
- [30] Y. I. Alzoubi and A. Mishra, "Green blockchain – A move towards sustainability," *Journal of Cleaner Production*, vol. 430, p. 139541, Dec. 2023, doi: 10.1016/j.jclepro.2023.139541.
- [31] C. M. Vivek, P. Ramkumar, P. K. Srividhya, and M. Sivasubramanian, "Recent strategies and trends in implanting of renewable energy sources for sustainability – A review," *Materials Today: Proceedings*, vol. 46, pp. 8204–8208, 2021, doi: 10.1016/j.matpr.2021.03.208.
- [32] A. Dutta, D. Park, G. S. Uddin, K. Kanjilal, and S. Ghosh, "Do dirty and clean energy investments react to infectious disease-induced uncertainty?," *Technological Forecasting and Social Change*, vol. 205, p. 123515, Aug. 2024, doi: 10.1016/j.techfore.2024.123515.
- [33] H. Wu, Z. Feng, T. Sun, R. Li, and H. Zhao, "Efficiency, sustainability, and resilience a trifecta for a green economic recovery through natural resource markets," *Resources Policy*, vol. 88, p. 104435, Jan. 2024, doi: 10.1016/j.resourpol.2023.104435.
- [34] J. Ramesh, M. Mohan Ram, and Y. S. Varadarajan, "Barrier mitigation strategies to the deployment of renewable and energy-efficient technologies (REET) in micro and small manufacturing clusters," *Materials Today: Proceedings*, vol. 52, pp. 1622–1632, 2022, doi: 10.1016/j.matpr.2021.11.273.
- [35] M. Shahbaz, A. Siddiqui, M. Siddiqui, Z. Jiao, and P. Kautish, "Exploring the growth of sustainable energy Technologies: A review," *Sustainable Energy Technologies and*

- Assessments*, vol. 57, p. 103157, Jun. 2023, doi: 10.1016/j.seta.2023.103157.
- [36] R. Shyam Narain, "Recent advancements and challenges in green material technology: Preparing today for nourishing tomorrow," *Materials Today: Proceedings*, Mar. 2023, doi: 10.1016/j.matpr.2023.02.218.
- [37] H. M. Valladares Montemayor and R. H. Chanda, "Automotive industry's circularity applications and industry 4.0," *Environmental Challenges*, vol. 12, p. 100725, Aug. 2023, doi: 10.1016/j.envc.2023.100725.
- [38] T. M. M. Abdellatif et al., "Novel variants conceptional technology to produce eco-friendly sustainable high octane-gasoline biofuel based on renewable gasoline component," *Fuel*, vol. 366, p. 131400, Jun. 2024, doi: 10.1016/j.fuel.2024.131400.
- [39] J.-H. Chang et al., "Green energy breakthroughs: Harnessing nano-catalysts and enzymatic catalysts for bioenergy generation," *Industrial Crops and Products*, vol. 215, p. 118527, Sep. 2024, doi: 10.1016/j.indcrop.2024.118527.
- [40] N. Daimary et al., "Musa acuminata peel: A bioresource for bio-oil and by-product utilization as a sustainable source of renewable green catalyst for biodiesel production," *Renewable Energy*, vol. 187, pp. 450–462, Mar. 2022, doi: 10.1016/j.renene.2022.01.054.
- [41] X. Yu, N. S. Sandhu, Z. Yang, and M. Zheng, "Suitability of energy sources for automotive application – A review," *Applied Energy*, vol. 271, p. 115169, Aug. 2020, doi: 10.1016/j.apenergy.2020.115169.
- [42] D. Esmaeili Aliabadi et al., "Future renewable energy targets in the EU: Impacts on the German transport," *Transportation Research Part D: Transport and Environment*, vol. 124, p. 103963, Nov. 2023, doi: 10.1016/j.trd.2023.103963.
- [43] J. R. Zhu, Y. Jin, W. Zhu, D.-K. Lee, and N. Bohlooli, "RETRACTED: Multi-objective planning of micro-grid system considering renewable energy and hydrogen storage systems with demand response," *International Journal of Hydrogen Energy*, vol. 48, no. 41, pp. 15626–15645, May 2023, doi: 10.1016/j.ijhydene.2022.12.279.
- [44] H. L. Oliveira et al., "Replacing oxygen evolution reaction in water splitting process by electrochemical energy-efficient production of high-added value chemicals with co-generation of green hydrogen," *Electrochimica Acta*, vol. 499, p. 144692, Sep. 2024, doi: 10.1016/j.electacta.2024.144692.
- [45] C. Li et al., "Assessing the prospect of deploying green methanol vehicles in China from energy, environmental and economic perspectives," *Energy*, vol. 263, p. 125967, Jan. 2023, doi: 10.1016/j.energy.2022.125967.
- [46] G. Loreti, A. L. Facci, and S. Ubertaini, "Combining renewable sources towards negative carbon emission hydrogen," *International Journal of Hydrogen Energy*, vol. 48, no. 54, pp. 20875–20888, Jun. 2023, doi: 10.1016/j.ijhydene.2023.03.177.
- [47] K. Singh et al., "India's renewable energy research and policies to phase down coal: Success after Paris agreement and possibilities post-Glasgow Climate Pact," *Biomass and Bioenergy*, vol. 177, p. 106944, Oct. 2023, doi: 10.1016/j.biombioe.2023.106944.
- [48] T. Rasheed et al., "Valorisation and emerging perspective of biomass based waste-to-energy technologies and their socio-environmental impact: A review," *Journal of Environmental Management*, vol. 287, p. 112257, Jun. 2021, doi: 10.1016/j.jenvman.2021.112257.
- [49] A. Yadav, A. K. Pandey, M. Samykano, T. Kareri, and V. V. Tyagi, "Wheat husk derived microparticle infused organic phase change material for efficient heat transfer and sustainable thermal energy storage," *Journal of Energy Storage*, vol. 86, p. 111204, May 2024, doi: 10.1016/j.est.2024.111204.
- [50] M. F. Roslan et al., "Techno-economic impact analysis for renewable energy-based hydrogen storage integrated grid electric vehicle charging stations in different potential locations of Malaysia," *Energy Strategy Reviews*, vol. 54, p. 101478, Jul. 2024, doi: 10.1016/j.esr.2024.101478.
- [51] G. Rani and D. K. Saini, "Need of Integrated Regional Planning Approach for the Decentralisation and Optimisation of Renewable Energy Based Electric Vehicle Infrastructure: A Comprehensive

- Visualisation," *Sustainability*, vol. 15, no. 18, p. 13315, Sep. 2023, doi: 10.3390/su151813315.
- [52] M. T. Rana, M. Numan, M. Yousif, T. Hussain, A. Z. Khan, and X. Zhao, "Enhancing sustainability in electric mobility: Exploring blockchain applications for secure EV charging and energy management," *Computers and Electrical Engineering*, vol. 119, p. 109503, Oct. 2024, doi: 10.1016/j.compeleceng.2024.109503.