European Research Studies Journal
Volume XXVIII, Issue 3, 2025

pp. 945-970

Renewable Energy Sources in Transport: Literature Review and Development Perspective

Submitted 20/07/25, 1st revision 09/08/25, 2nd revision 26/08/25, accepted 23/09/25

Patrycja Guzanek[1], Anna Borucka[2], Marcin Kęsy[3]

Abstract:

Purpose: *The transportation sector is crucial for achieving global sustainability goals, particularly in reducing greenhouse gas emissions and transitioning away from fossil fuels. This study aims to provide a comprehensive overview of research on renewable energy sources (RES) in transportation, identifying key trends, thematic clusters, and research gaps to support both academic and policy development in transport decarbonization.*
Design/Methodology/Approach: *A systematic bibliometric analysis was conducted using Scopus-indexed publications. VOSviewer software was applied to map publication trends, co-authorship networks, and thematic clusters, enabling the identification of dominant research streams and patterns of institutional collaboration.*
Findings: *The analysis highlights three primary research streams: hydrogen technologies, electric mobility, and biofuels. China emerges as the leading country in terms of both publication output and collaboration intensity, followed by Europe and the United States. Furthermore, the study reveals underexplored areas in integrating renewable energy into transportation systems, signaling opportunities for future research.*
Practical Implications*: The findings provide actionable insights for policymakers and industry stakeholders seeking to accelerate the transition toward sustainable transport. By identifying active research areas and gaps, the study supports strategic decision-making in funding allocation, technology development, and international cooperation.*
Originality/Value: *This study offers a data-driven and systematic perspective on the evolution of research related to RES in transportation. It uniquely combines bibliometric mapping with a focus on transport decarbonization, providing valuable input for scholars and practitioners working toward climate-neutral mobility systems.*

Keywords: *Transportation, bibliometric analysis, hydrogen technologies, electric vehicles, co-authorship network, keyword co-occurrence.*

JEL Code: *Q42, R40, O18.*

Paper Type: *Bibliometric review paper.*

[1]*Military University of Technology, Poland, ORCID:0000-0001-6650-7187,*
e-mail: patrycja.guzanek@student.wat.edu.pl;
[2]*Military University of Technology, Poland, ORCID: 0000-0002-7892-9640,*
e-mail: anna.borucka@wat.edu.pl;
[3]*Pomeranian Higher School in Starogard Gdanski, Poland, ORCID: 0000-0003-3604-4702,*
e-mail: marcin.kesy@twojestudia.pl;

1. Introduction

The modern transportation sector faces urgent challenges such as the reduction of greenhouse gas emissions, fossil fuel dependence, and the pursuit of improved energy efficiency. These challenges are global in scope and critical for meeting international climate goals (Sinha and Shahbaz, 2022; Lindstad, Watkins, and Strømman, 2023; Adamiak, Andrych-Zalewska, Merkisz, and Chłopek, 2025).

Transportation accounts for a significant proportion of global energy use and CO_2 emissions, necessitating a shift toward cleaner energy systems (Gielen *et al.,* 2019; Ajanovic and Haas, 2021; Andrych-Zalewska *et al.,* 2024). In response to these challenges, increasing attention is being directed toward renewable energy sources (RES) (Andrych-Zalewska *et al.,* 2024), such advanced biofuels, green hydrogen, solar and wind-powered systems, and electric vehicles represent viable alternatives to conventional fossil-based systems in all major transport modes, including road, rail, aviation, and maritime (Lindstad, Watkins, and Strømman, 2023; Jaroń and Borucka, 2024).

The development of technologies based on renewable energy sources is a crucial element of global strategies aimed at building a sustainable transportation system (Gielen *et al.,* 2019; Ajanovic and Haas, 2021). In particular, international and national policies promote the implementation of environmentally friendly solutions, such as transport electrification, the introduction of second- and third-generation biofuels, and the advancement of hydrogen technologies (Sinha and Shahbaz, 2022; Žvirblis *et al.,* 2023; Chen and Wang, 2025; Sayeed and Manikandan, 2024).

Despite the dynamic growth in research in this field, there remains a need for a systematic literature review that will identify key trends, challenges, and future research directions (Ajanovic and Haas, 2021, Lindstad, Watkins, and Strømman, 2023).

Systematic literature reviews (SLRs) are essential in synthesizing existing research, identifying gaps, and guiding future studies across various disciplines (Fahimnia *et al.,* 2015; Zhang, Guhathakurta, and Khalil, 2023). In the field of transportation, numerous SLRs have been conducted to address diverse topics, reflecting the growing complexity and interdisciplinary nature of transportation research (Fahimnia *et al.,* 2015; Zuo *et al.,* 2021). Several SLRs have been published in transportation research, addressing a wide array of topics.

For instance, a comprehensive review focused on collaborative sustainable transportation in the freight sector, analyzing 89 studies to understand the integration of sustainability and collaboration in freight transport operations (Fahimnia *et al.,* 2015). Another study systematically reviewed the applications, impacts, and public perceptions of autonomous vehicles in road transportation, providing insights into the societal acceptance and technological advancements of autonomous driving

(Zhang, Guhathakurta, and Khalil, 2023). Additionally, a systematic review examined urban transportation sustainability assessments, offering a critical overview of methodologies used to evaluate sustainability in urban transport systems (Zuo *et al.,* 2021).

SLRs serve multiple critical functions in academic research as synthesizing existing knowledge (Fahimnia *et al.,* 2015; Zhang, Guhathakurta, and Khalil, 2023) and identifying research gaps (Aloi *et al.,* 2021). The prevalence of systematic literature reviews in transportation research underscores their significance in advancing the field. By critically evaluating existing studies, these reviews contribute to a deeper under-standing of complex transportation issues, guide future research directions, and inform evidence-based policy and practice.

As transportation systems continue to evolve, the role of SLRs in synthesizing knowledge and identifying emerging trends will remain indispensable (Fahimnia *et al.,* 2015; Aloi *et al.,* 2021).

This study aims to provide an updated and comprehensive overview of the scientific literature on RES in transportation, identifying current technological trends, research gaps, and future directions. Its novelty lies in mapping interdisciplinary research clusters and institutional networks while emphasizing hydrogen technologies and transport electrification as dominant global research priorities.

The novelty of this study lies in its com-prehensive bibliometric analysis of RES research in transport, which allows for the identification of global trends, institutional patterns, and thematic gaps in a systematic and data-driven manner - offering a broader strategic perspective compared to traditional literature reviews.

The rest of the article is structured as follows: Section 2 presents the methodology used for bibliometric analysis; Section 3 details the main findings; Section 4 discusses the implications and limitations; and Section 5 concludes with recommendations for future research.

2. Research Methodology

The objective of this study is to conduct a comprehensive bibliometric analysis of scholarly publications addressing the use of renewable energy sources (RES) in transportation. The analysis focuses on publication volume, temporal trends, leading institutions, and thematic areas of research.

To perform the bibliometric analysis, data were retrieved from the Scopus database, known for its extensive indexing of peer-reviewed publications. A structured search strategy combining keywords related to RES and transportation was employed.

VOSviewer software was used to analyze co-authorship networks, keyword co-

occurrence patterns, and citation impacts. The methodology included six stages: (1) defining research questions, (2) retrieving data, (3) cleaning data, (4) analyzing results, and (5) interpreting trends.

- *Step 1: Definition of Research Questions*

The first stage involved establishing specific research questions (RQs) to guide the biblio-metric analysis:

RQ1: Which countries have made the most significant contributions to the research field?
RQ2: Which institutions published the biggest number of articles related to the RES in transportation?
RQ3: What are the key thematic areas and research clusters in the domain of RES in transport?

These questions provide the foundation for subsequent data retrieval, analysis, and interpretation.

- *Step 2: Data Collection*

To conduct a robust bibliometric analysis of the academic discourse surrounding the implementation of renewable energy sources (RES) in transport, a structured search strategy was designed and applied to the Scopus database. Scopus was selected for its extensive indexing of peer-reviewed literature, as well as its advanced filtering and export functionalities, making it a suitable tool for quantitative research mapping.

General query used for RES in transport in this study:

(TITLE-ABS-KEY("renewable energy" OR "renewable energy sources" OR "biofuels" OR "hydrogen" OR "solar energy" OR "wind energy")

AND TITLE-ABS-KEY("transport" OR "mobility" OR "vehicles" OR "aviation"

OR "ship-ping" OR "logistics"))

AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp"))

AND (LIMIT-TO(LANGUAGE, "English"))

AND (LIMIT-TO(PUBSTAGE, "final"))

The query was designed to capture a broad range of publications addressing the integration of RES technologies within various transport sectors, including road,

maritime, aviation, and logistics.

- *Step 3: Data Cleaning and Preparation*

After retrieving the raw dataset, duplicate records, non-relevant entries, and incomplete publications were filtered out. The inclusion criteria required that articles be:

- Published in peer-reviewed journals or conference proceedings.
- Focused specifically on renewable energy in transport, as indicated in the title, abstract, or keywords.
- Available in English to ensure broad accessibility and comparability.

The 20 000 documents were selected after application of the query presented above.

- *Step 4: Data Analysis and Visualization*

A bibliometric analysis was conducted using VOSviewer, which allow for network map-ping, keyword co-occurrence analysis, and citation analysis. The analysis involved:

- Publication trends: Determining annual output to assess the growth of interest in the field.
- Citation analysis: Identifying the most influential papers based on citation count.
- Authorship and institutional contributions: Mapping key contributors, collaborations, and geographic distribution of research output.
- Thematic clustering: Employing co-word analysis to identify major research themes and emerging topics in RES applications in transport.

- *Step 5: Interpretation of Results*

The results were analyzed in relation to existing literature, highlighting key advancements, dominant research trends, and potential gaps in knowledge. This step provided context to the findings, ensuring their relevance to both academic and industry stakeholders.

3. Research Results and Discussion

The bibliometric analysis identified key geographical and institutional contributors to RES research in transportation, with China, Germany, and the United States leading in both output and influence. Collaboration clusters were prominent within Asia and Europe, reflecting regional policy initiatives and shared infrastructure goals.

Co-authorship maps revealed strong international partnerships. However, developing regions such as Africa and South America also show emerging participation, especially in areas of bioenergy and hydrogen systems.

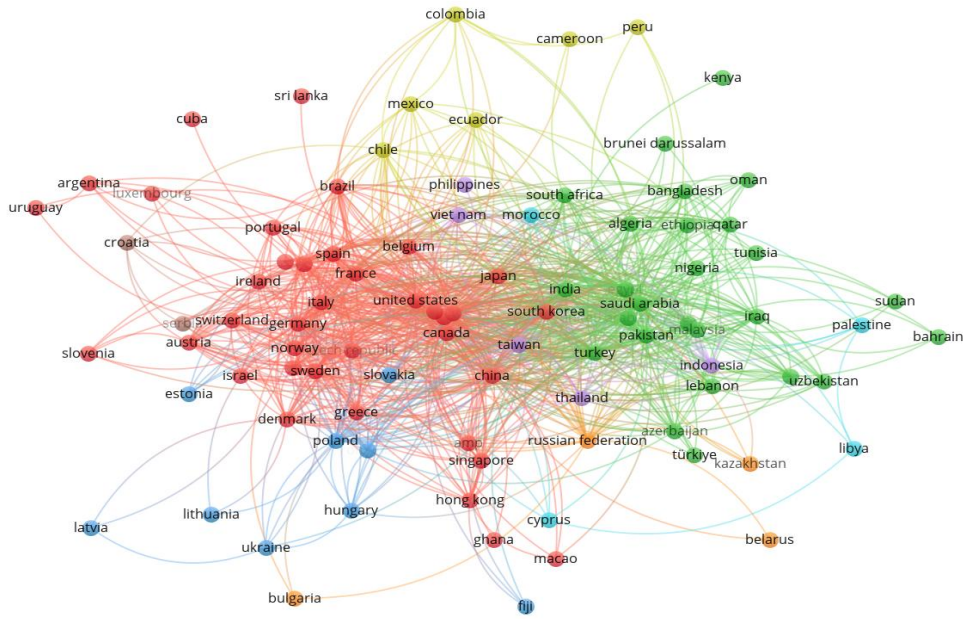
The keyword co-occurrence analysis revealed distinct clusters. Dominant themes included hydrogen fuel production, electric vehicles, biofuels, and emissions reduction. Keywords related to biomedical fields, identified initially, were filtered out in refined analysis to focus on transport-relevant topics.

The study reveals a clear global convergence around decarbonization, with national priorities shaping specific research. A need remains for broader exploration of RES integration in maritime and rail systems, which appear underrepresented.

3.1 Co-Authorship Network Among Countries (RQ1: Which countries have made the most significant contributions to the research field?)

The first research question focuses on identifying the countries that have contributed most significantly to the scientific discourse on renewable energy sources (RES) in transport. By analyzing country-level collaboration and publication patterns, this section highlights the geographical distribution of research activity in this field.

Figure 1. *Co-Authorship Network Among Countries presented on a graph.*



Source: *Own study.*

The co-authorship analysis was conducted to identify key contributing countries and their collaborative relationships in the research on renewable energy sources (RES) in transport. Figure 1 presents a network visualization generated using VOSviewer, based on 94 countries, grouped into eight clusters according to co-authorship patterns.

The green cluster includes major contributors such as China, India, Saudi Arabia, South Africa, Nigeria, Turkey, and Pakistan. These countries exhibit strong collaborative links, particularly within Asia and Africa, indicating the increasing involvement of emerging economies in RES-related transport research. The growing participation of countries from the Global South suggests that sustainable transport and energy transition are gaining traction beyond traditionally dominant regions.

The red cluster primarily consists of Western and Southern European countries, including France, Germany, Italy, Spain, and the United Kingdom, along with the United States and Canada. This group demonstrates dense collaboration networks, reflecting historical leadership in transport decarbonization research. Notably, the United States appears as a central node in the network, emphasizing its influence on shaping the global scientific discourse on RES in transport.

The blue cluster aggregates countries from Central and Eastern Europe, such as Poland, Hungary, Lithuania, Ukraine, and Bulgaria. The regional character of this cluster may be associated with the influence of European Union research programs (e.g., Horizon Europe) and cross-border initiatives targeting transport sustainability.

Smaller clusters, such as the orange cluster (e.g., Belarus, Kazakhstan) and yellow cluster (e.g., Mexico, Colombia, Cameroon), highlight more regionally focused partnerships, yet maintain moderate links with larger clusters, indicating peripheral but active participation.

While there is evident globalization of RES and transport research, regional alliances still play a decisive role, especially within Europe, Asia, and Africa. Western countries continue to act as knowledge hubs, yet there is a growing diversification, with countries from Africa, the Middle East, and South America forming tighter collaborative networks.

The analysis of country-level contributions reveals that China is the leading country in terms of research output related to renewable energy sources (RES) in transport. Other prominent contributors include the United States, Germany, and several Western

European countries, such as France, the United Kingdom, and Italy. Additionally, countries from emerging economies, particularly India, Saudi Arabia, and South Africa, also show significant engagement in the field. The findings indicate a concentration of re-search activity in Asia, North America, and Europe, reflecting

both regional policy priorities and the scientific capacity of these countries. The collaboration networks further high-light strong ties between Chinese institutions and partners in Europe and other parts of Asia.

A review of the most recent publications in the field of renewable energy sources (RES) in transport highlights distinct thematic patterns across geographic regions. While there is clear global convergence around decarbonization and energy transition, regional research efforts tend to emphasize topics tailored to local energy systems, infrastructure, and policy priorities.

In China, research is heavily focused on hydrogen technologies and electrochemical energy systems. Scholars investigate catalyst nanostructures, electrolyte engineering, and hydrogen evolution efficiency. Guo *et al.* (2025) explore nanobubble nucleation to improve electrocatalysis, while Zhang *et al.* (2025a) propose novel passivators for high-performance solar cells, and Zhang *et al.* (2025b) introduce confinement-induced Ni-based materials for enhanced deionization in water purification systems (Zhang, Wang, and Guo, 2025).

Germany and France contribute through advances in catalyst materials and zeolitic diffusion for clean energy processes. Bjerregaard *et al.* (2025) study aluminium distribution effects in Cubased catalysts.

In the United States, India, and South Africa, the research focus shifts toward bioenergy and waste-to-energy technologies. Lower *et al.* (2025) develop kinetic models for anaerobic digestion and biogas production, while Lei *et al.* (2025) investigate peroxidase-based systems with biomedical applications, and Begum *et al.* (2025) explore frequency stability in EV-integrated power systems.

Saudi Arabian and Middle Eastern institutions show growing interest in CO_2 conversion and recovery technologies. Wang *et al.* (2025) present an integrated system for electrolyte recovery and carbon capture in electrochemical reduction. Emerging themes such as energy supply chain resilience and sustainability assessment are being addressed by researchers like (Labaran and Masood, 2025), who analyze systemic challenges in renewable logistics.

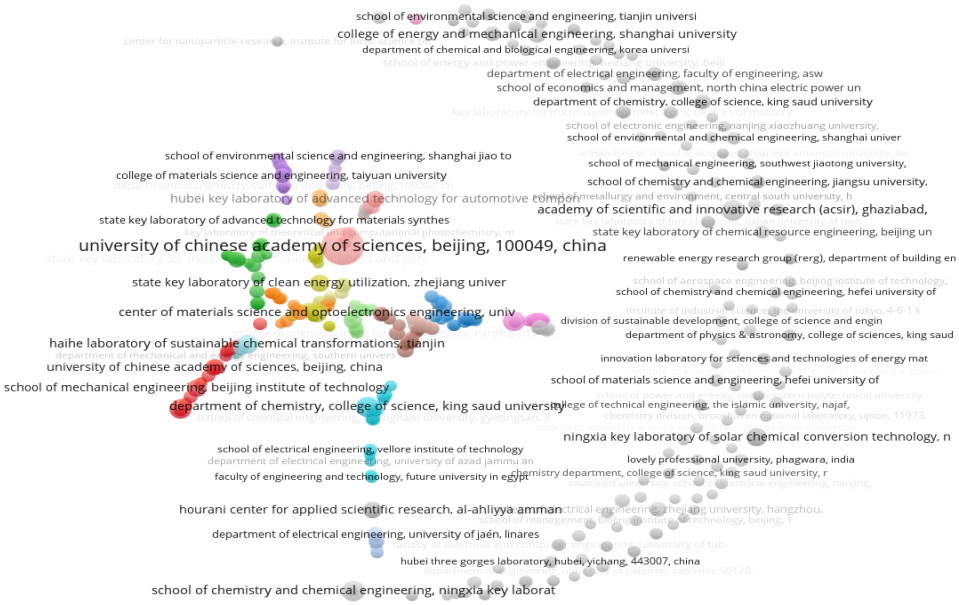
Although national strategies and local constraints influence the direction of research, shared challenges - such as energy storage, system stability, and emission reduction - create a platform for international collaboration and knowledge exchange across disciplines.

3.2 Institutional Productivity Analysis (RQ2: Which Institutions Published the Biggest Number of Articles Related to RES in Transportation?)

This section addresses the second research question by examining which institutions have been the most active in publishing research on renewable energy sources (RES)

in transportation. The analysis provides insights into the key academic and research centers driving the development of knowledge in this domain, based on institutional-level publication and collaboration data.

Figure 2. *Institutional Productivity Analysis presented on a graph*



Source: *Own study.*

The institutional collaboration map generated with VOSviewer (Figure 2) highlights the most prolific institutions contributing to the field of renewable energy sources (RES) in transportation. The visualization is based on co-authorship data and institutional affiliations extracted from Scopus-indexed publications.

At the center of the network is the University of Chinese Academy of Sciences, Beijing, which stands out as the most active institution in terms of publication volume. Its dominant position suggests a strong commitment to research in RES technologies, with a likely emphasis on hydrogen production, renewable fuels, and transport-related applications.

Other highly active institutions include:

- State Key Laboratory of Clean Energy Utilization, Zhejiang University,
- Hubei Key Laboratory of Advanced Technology for Automotive Components,
- Beijing Institute of Technology,
- Shanghai Jiao Tong University.

These institutions are particularly clustered around Chinese research centers, underscoring China's leadership role in RES research related to the transport sector. This pat-tern aligns with China's national strategies promoting energy transition and low-carbon mobility.

The dominance of Chinese research institutions in the network suggests that China is currently one of the global leaders in producing scientific output related to RES in transport. The visibility of research centers from India, Jordan, and Saudi Arabia high-lights growing interest in sustainable transport solutions in other parts of Asia and the Middle East.

In addition to measuring publication volume, citation analysis was performed to identify which institutions not only publish the most but also generate the highest impact within the research field of RES in transportation. Figure 3 presents the institutional citation map based on total citations received.

Figure 3. *Institutional Productivity Analysis with citation volume presented on a graph.*

Source: *Own study.*

Similar to the productivity analysis, the University of Chinese Academy of Sciences, Beijing remains the most influential institution, occupying a central position in terms of citation strength. This confirms its dual role as both a prolific and highly cited research center in the domain of renewable energy applications for transport.

Other institutions with high citation impact include:

- Zhejiang University (State Key Laboratory of Clean Energy Utilization),
- Beijing Institute of Technology,
- Shanghai Jiao Tong University,
- Tsinghua University,
- King Saud University.

The map also reveals that several Chinese national laboratories and research centers, such as the Hubei Key Laboratory of Advanced Technology and Haihe Laboratory of Sustainable Chemical Transformations, show significant citation linkages, suggesting their outputs are well-recognized in the global academic community.

Interestingly, Saudi Arabia's King Saud University and several Indian and Jordanian research institutes also ap-pear in the citation network, albeit with lower density, indicating emerging contributions to influential research streams.

Institutions from China dominate both in terms of productivity and citation performance, confirming their leadership in the global RES transport research landscape. Middle Eastern and South Asian institutions, while publishing fewer papers, are starting to produce work that garners growing academic attention.

The analysis of institutional productivity and citation impact highlights a strong dominance of Chinese research institutions in the field of renewable energy sources in transport. The University of Chinese Academy of Sciences emerged as the most prolific and influential contributor, accompanied by other key players such as Zhejiang Universi-ty, Beijing Institute of Technology, and Tsinghua University.

These institutions are at the forefront of research related to hydrogen technologies, energy storage systems, and renewable energy integration into transport infrastructures.

The citation analysis further reinforces this trend, as Chinese institutions not only publish a large number of papers but also generate significant scholarly impact. Emerging research centers from Saudi Arabia, India, and Jordan are also visible in the citation map, signaling increasing engagement from other regions with growing sustainable transport agendas.

This dual analysis demonstrates the concentration of research leadership in China, but also hints at a gradual diversification of knowledge production across other parts of Asia and the Middle East.

An additional dimension of the bibliometric analysis concerns the thematic scope of research across different institutions. The dataset reveals that the three most prolific institutions, based on author affiliations in the Scopus-indexed publications, are:

The Indian Institute of Technology, and the Indian Institute of Science.

These institutions contribute extensively to research in hydrogen technologies, fuel cell systems, and advanced functional materials for energy conversion (Gonda *et al.,* 2025).

The University (various global universities with "University" in the name, e.g., University of Science and Technology of China, University of California). Their publications span multiple areas including solar energy harvesting, hybrid energy systems, and environmental impact assessments related to transport (Li *et al.,* 2025).

National Institute (e.g., National Institute of Technology, National Renewable Energy Laboratory). The dominant topics include bioenergy conversion, thermal processes, and power system integration of RES (Azadmanesh *et al.,* 2025).

To better understand how different types of institutions contribute to the development of RES in transport, publications were grouped into three categories: Technical Universi-ties, Natural Sciences Institutions, and Energy/Environmental Research Centers.

Researchers affiliated with Technical Universities focus strongly on engineering aspects of energy systems. For instance, recent work from these institutions includes advancements in nanostructured electrodes and supercapacitor materials for electric transport applications (Zhang *et al.,* 2025), as well as structural analysis of CO_2 reduction mechanisms and electrochemical device optimization (Mostek-Majewska *et al.,* 2025).

Natural Sciences Institutions are more frequently involved in fundamental studies on reaction mechanisms, molecular catalysis, and interface design for energy efficiency. Their contributions support the development of novel catalysts and nanoenzymes applicable to both stationary and mobile energy systems (Liziczai *et al.,* 2025; Ghaedi and Gholami, 2025).

Meanwhile, Energy and Environmental Institutions contribute through integrative systems research, covering topics such as grid resilience in the context of renewable transport energy, CO_2 recycling, and sustainable logistics.

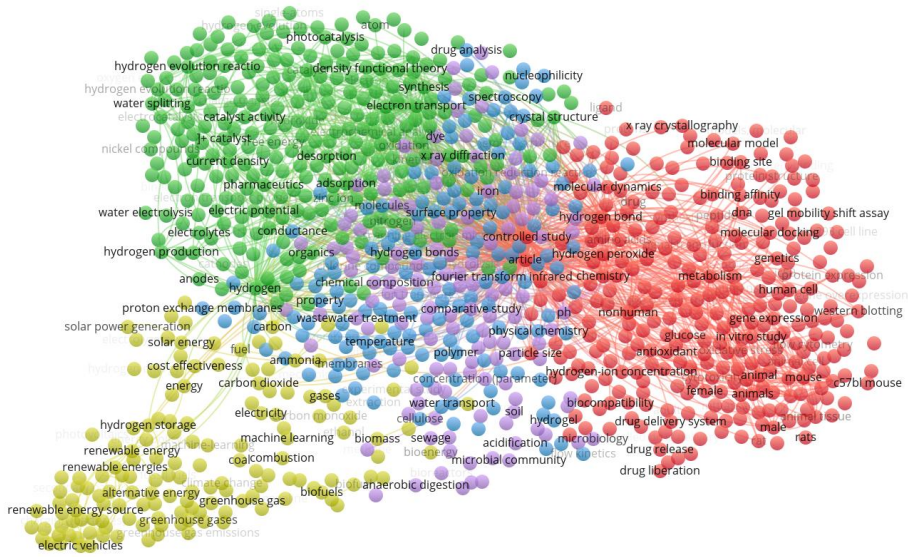
Their publications are often high-light holistic approaches to carbon management, system-level modeling, and infrastructure scaling (Berdiyorov, 2025; Xu *et al.,* 2025).

This differentiation underscores the diversity of academic perspectives shaping RES and transport research. While technical universities emphasize innovation in materials and devices, environmental institutions focus more on system integration and sustainability frameworks.

3.3 Co-occurrence Network of Keywords (RQ3: What are the key thematic areas and research clusters in the domain of RES in transport?)

To answer the third research question, this section explores the key thematic areas and research clusters within the domain of renewable energy sources (RES) in transport. By analyzing the co-occurrence of keywords, the study identifies dominant research streams and emerging topics that structure the current scientific landscape in this field.

Figure 4. *Co-occurrence Network of Keywords presented on a graph.*



Source: *Own study.*

Figure 4 above presents a keyword co-occurrence map based on author keywords extracted from the Scopus dataset, visualized using VOSviewer.

The map reveals several distinct thematic clusters, each representing dominant research streams in the field of renewable energy sources (RES) in transport and related areas.

Yellow Cluster (Bottom-left corner): This cluster focuses on overarching themes directly linked to renewable energy in the transport sector, including terms such as “renew-able energy”, “renewable energy sources”, “electric vehicles”, “biofuels”, “greenhouse gases”, and “climate change”.

The co-occurrence of terms like “alternative energy”, “car-bon dioxide”, and “decarbonization” suggests a thematic emphasis on the environmental impact of transportation and the decarbonization of mobility systems.

Green Cluster (Center-Left): The dominant cluster in terms of node density, it is primarily associated with technical aspects of hydrogen technologies and water electrolysis. Keywords such as “hydrogen production”, “water electrolysis”, “hydrogen evolution re-action”, “electrolytes”, and “current density” reflect a strong focus on hydrogen-based solutions, highlighting their relevance for the future of zero-emission transport.

Red Cluster (Right side): This group is oriented around biomedical and materials science keywords such as “molecular docking”, “metabolism”, “drug delivery system”, and “gene expression”. While tangential to transport, this may indicate interdisciplinary overlaps, where materials and chemical sciences contribute to innovations in fuel cells, biocompatible materials, and advanced energy carriers.

Blue Cluster (Center-Bottom): This smaller group is characterized by keywords related to “biomass”, “sewage”, “anaerobic digestion”, and “bioenergy”. It reflects a stream of research dedicated to circular economy principles and bioenergy recovery processes, which are relevant for waste-to-energy strategies within transport systems.

Purple Cluster (Center): This cluster serves as a thematic bridge between hydrogen research and bioenergy, with terms like “polymer”, “hydrogel”, “surface property”, and “biocompatibility”, suggesting material science applications in RES, possibly for mem-branes, electrodes, or advanced storage systems.

Upon examining the initial keyword co-occurrence map (Figure 4), it was observed that one of the major thematic clusters-the red cluster-was primarily composed of terms related to biomedical and material sciences, such as “molecular docking”, “metabolism”, “drug delivery system”, and “gene expression”.

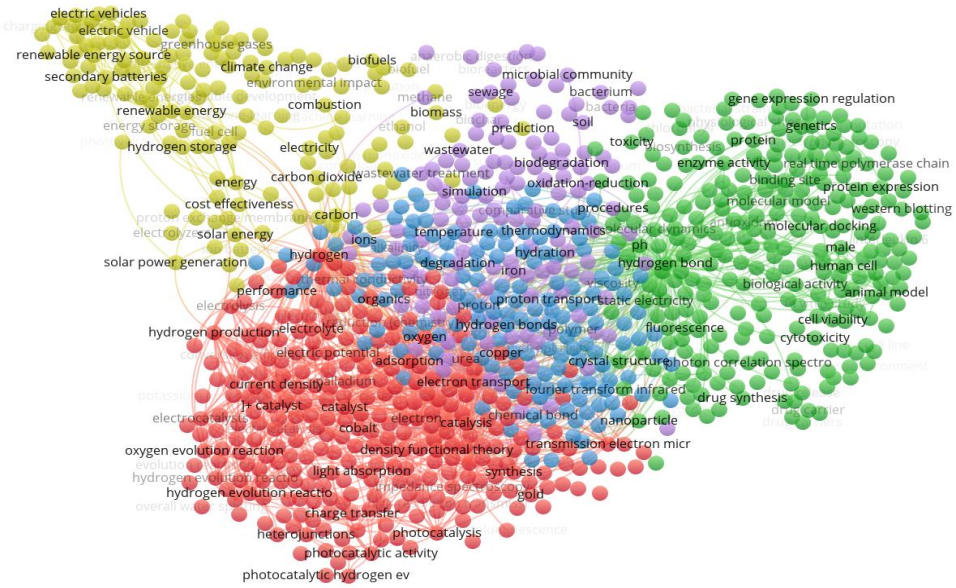
While these topics suggest potential interdisciplinary links, particularly regarding innovations in fuel cells, biocompatible membranes, or advanced energy carriers, they are largely peripheral to the core objective of this study, which focuses on renewable energy applications in transport.

To ensure higher thematic relevance and sharper focus on transport-related energy systems, the keyword analysis was refined by applying a minimum occurrence threshold of 50.

This adjustment reduced the presence of keywords originating from domains tangential to transport and highlighted the most dominant and transport-oriented research streams.

The resulting map, presented in Figure 5, provides a clearer and more targeted over-view of the principal research themes in the field, aligned with the scope of RES implementation in transport systems.

Figure 5. *Co-occurrence Network of Keywords with restrictions presented on a graph.*



Source: *Own study.*

Following the refinement of the keyword co-occurrence analysis, Figure Z presents the updated network visualization with a minimum occurrence threshold set at 50. This adjustment significantly reduced the presence of peripheral biomedical terms, ensuring a sharper focus on the core themes associated with renewable energy sources (RES) and their application in transport systems.

The most transport-focused cluster contains keywords such as “electric vehicles”, “renewable energy”, “biofuels”, “climate change”, “greenhouse gases”, and “hydrogen storage”. This cluster clearly relates to sustainable transport solutions and policy-relevant themes, such as decarbonization pathways, environmental impact mitigation, and electric mobility. Recent studies reflect this orientation.

Labaran and Masood (2025) analyze sustainability and supply chain challenges in renewable energy applications. Mizuno *et al.* (2025) explore photovoltaic-based renewable electricity integration in mobility systems, while Zenhom *et al.* (2025) investigate the coexistence of distributed generation and electric vehicle networks in emerging markets.

This cluster centers on electrochemical and hydrogen-related processes, with dominant terms like “hydrogen production”, “electrolyte”, “oxygen evolution reaction”, “catalyst”, and “current density”. The strong technical focus suggests that hydrogen and electrochemical systems remain a pivotal research domain within RES and transport. For instance, Wang *et al.* (2025) present an integrated electrolysis

system for hydrogen and CO_2 recovery. Zhang *et al.* (2025) design cobalt-based nano-island catalysts to enhance oxygen evolution and system stability. Additional work focuses on improving catalyst efficiency through active surface structuring (Bukhari *et al.,* 2025).

Oriented toward bioenergy and waste-to-energy topics, this group includes terms like "biomass", "anaerobic digestion", "wastewater treatment", and "microbial community". This reflects the growing academic interest in circular economy solutions and bio-based fuels as part of the broader RES portfolio for transport. Recent work by Lee *et al.* (2025) and Chatterjee *et al.* (2025) explores microbial conversion systems, integrated biorefineries, and the optimization of anaerobic digestion parameters for energy recovery in transport and urban systems.

Although partially still dominated by materials science and biochemistry terms such as "gene expression", "cytotoxicity", and "protein expression", the cluster also intersects with research on advanced materials and biocompatibility, relevant for components like fuel cell membranes and electrochemical devices. Several studies from this group investigate nanomaterials for biomedical-electrochemical hybrid applications, membrane durability, and biocompatibility optimization for transport-related fuel systems.

Positioned between the hydrogen and bioenergy clusters, the final group covers cross-cutting topics such as "hydrogen bonds", "thermodynamics", "degradation", and "fluorescence", pointing toward fundamental chemical and physical research underlying RES technologies. Key studies include Mendoza *et al.* (2025), More *et al.* (2025) and Li *et al.* (2025), addressing spectroscopic properties of fuel materials, thermal degradation behavior of hydrogen carriers, and bond energy studies in advanced battery chemistries.

The refined map provides a clearer picture of the dominant research directions:

- Strong emphasis on electric mobility and decarbonization.
- Continued technological focus on hydrogen systems and electrolysis.
- Active exploration of bioenergy and waste valorization pathways for energy production.
- Interdisciplinary research links to advanced materials and catalytic processes.

The improved visualization confirms that despite prior overlaps with biomedical sciences, the core research landscape remains centered around sustainable transport and renewable energy integration, particularly through hydrogen and electrification technologies.

The presence of biomedical and materials science keywords in the initial co-occurrence analysis highlights the interdisciplinary nature of some research streams

intersecting with RES in transport. While these biomedical-related terms are not directly aligned with transport-focused studies, their appearance may be attributed to shared methodologies and innovations applicable across domains, such as the development of biocompatible materials for fuel cells or advanced storage technologies.

However, after refining the keyword map to prioritize higher-frequency, transport-related terms, the core research landscape more clearly converged around sustainable transport topics. This confirms that, although there are interdisciplinary overlaps, the predominant focus of the research community remains centered on renewable energy integration in transport systems, with hydrogen technologies and electrification emerging as the leading areas of interest.

The bibliometric analysis identified several dominant renewable energy technologies in transport research, including electric vehicles, hydrogen systems, and advanced biofuels. To clarify how these technologies are typically modeled in academic studies, Table 1 presents a synthesis linking each RES type with corresponding analytical methods and their primary applications.

***Table 1**. RES type with corresponding analytical methods and their primary applications.*

RES Technology	**Analytical/Modeling Method**	**Typical Application**	**Research Focus Area**
Electric Vehicles (EVs)	Optimization, Agent-Based Models, AI	Charging station planning, energy consumption	Urban mobility, EV grid integration
Hydrogen Fuel Cells	MILP, Simulation, Graph Theory	Distribution infrastructure, energy storage	Hydrogen production and logistics
Advanced Biofuels	Life Cycle Analysis (LCA), Supply Chain Models	Emission reduction, production scalability	Sustainable fuel sourcing and logistics
e-Fuels / Power-to-X	Thermodynamic and Network Models	System-level integration with RES	Cross-sector energy conversion pathways
Solar/Wind-Powered Transport	Multi-objective Optimization, Forecasting	Direct or indirect integration with vehicles	Variability management, grid resilience

***Source:** Own study.*

4. Discussion

The bibliometric analysis conducted in this study provides a comprehensive overview of research trends related to the application of renewable energy sources (RES) in the transport sector. Several key insights emerge from the analysis, which together illustrate the maturity and evolving structure of this research domain.

First, the country-level co-authorship network reveals the dominance of China, alongside significant contributions from the United States and Western European countries. China's leadership is particularly pronounced in both research productivity and citation impact, reflecting its national commitment to advancing low-carbon transport technologies. The involvement of institutions from India, Saudi Arabia, and other emerging economies also signals the growing global engagement in this field.

At the institutional level, Chinese universities and research centers such as the University of Chinese Academy of Sciences and Zhejiang University play a pivotal role in driving innovation and collaboration within the RES and transport nexus. However, emerging players from the Middle East and South Asia are beginning to strengthen their research output and international presence, suggesting a gradual diversification of the research landscape.

The keyword co-occurrence analysis revealed clear thematic clusters. Hydrogen technologies and electrochemical processes form one of the most dominant research streams, supported by a strong focus on electric vehicles, biofuels, and greenhouse gas mitigation strategies. Thematic clusters related to waste-to-energy systems and biomass also highlight the relevance of circular economy principles in supporting transport decarbonization.

An interesting observation arose during the initial keyword analysis, where an overlap with biomedical and materials science terms was identified. While these topics suggest interdisciplinary synergies-especially in the context of fuel cell development and advanced materials for transport applications-such overlaps were reduced after refining the dataset. The improved visualization reaffirmed that the core research landscape remains firmly focused on sustainable mobility and RES integration, particularly through hydrogen technologies and electrification pathways.

This study confirms China's dominant role in RES transport research, supported by high output and citation impact. Similar prominence is observed for European countries and the United States, whose institutions form the backbone of global collaboration networks.

Hydrogen technology and electrification emerge as the most extensively studied domains. Their maturity and alignment with policy trends underscore their strategic relevance. Biofuels and waste-to-energy clusters also indicate strong support for circular economy models.

In order to understand how different renewable energy solutions are analyzed and implemented in the transport sector, it is essential to review the mathematical and computational models used in current research. Table 2 provides an overview of modeling approaches applied in transport decarbonization studies, highlighting their application areas and purpose.

***Table 2**. Overview of modeling approaches applied in transport decarbonization studies.*

Modeling Approach	Application Area	Description / Purpose
Linear/Nonlinears Programming (LP/NLP)	Energy cost optimization, route efficiency	Minimizing cost, fuel use, or emissions in RES transport scenarios
Mixed-Integer Linear Programming (MILP)	Infrastructure planning, station placement	Modeling discrete decisions like station siting or schedule design
Stochastic/Dynamic Programming	Uncertainty handling in demand, weather, energy prices	Planning under variability and risk
Multi-Objective Optimization	Trade-off analysis (cost vs. emissions vs. time)	Balancing multiple competing objectives
Agent-Based Modeling	User behavior, charging patterns	Simulation of individual user interactions in transport networks
Monte Carlo Simulation	System performance under uncertainty	Probabilistic scenario modeling
Machine Learning / Neural Networks	Energy demand forecasting, SoC estimation	Predictive models based on large datasets
Reinforcement Learning	Smart charging and route optimization	Decision-making through trial-and-error learning
Graph Theory / Network Models	Infrastructure layout, grid integration	Optimizing network structure and connectivity

***Source:** Own study.*

To support the development and integration of renewable energy technologies in the transport sector, recent studies increasingly rely on structured mathematical and computational modeling. The modeling approaches typically begin with optimization models, such as linear and nonlinear programming, which are widely used for cost minimization and emission reduction in energy systems.

More advanced applications involve mixed-integer linear programming (MILP) to support discrete decision-making processes, such as the optimal placement of electric charging stations or hydrogen refueling infrastructure. In parallel, stochastic and dynamic programming approaches enable planning under uncertainty, including variations in energy demand, weather conditions, or electricity pricing. Multi-objective optimization is also applied to balance competing priorities, such as minimizing cost while maximizing environmental and operational efficiency.

Building on these methods, researchers employ simulation models to evaluate complex system behaviors. For example, agent-based modeling is used to simulate the behaviors and charging patterns of electric vehicle users within urban mobility systems, while Monte Carlo simulations assess system performance, variability, and risk under uncertain scenarios.

Recent advancements also include the application of machine learning and artificial intelligence. Predictive models, such as neural networks, are used to forecast energy

demand and estimate battery state of charge (SoC) and degradation. Reinforcement learning techniques are gaining popularity for smart charging control, enabling adaptive and real-time optimization of energy usage in electric vehicle fleets.

Finally, network and infrastructure models-often based on graph theory-are utilized to design optimal energy distribution systems. These models support planning of grid integration points, spatial distribution of renewable charging stations, and efficient infrastructure deployment.

Beyond the dominant research areas of hydrogen and electrification, literature also highlights practical applications of RES technologies across specific transport sectors. In public transport, electric buses and hydrogen-powered trains are increasingly adopted in urban and regional mobility systems, driven by national and municipal decarbonization goals. In the logistics sector, electric delivery fleets and advanced biofuels contribute to reducing emissions from freight transport, supported by routing optimization models and supply chain assessments.

A substantial body of research also addresses EV charging infrastructure planning, applying MILP and network-based models to determine optimal locations, manage load balancing, and ensure grid compatibility. Furthermore, applications in maritime and aviation are emerging, particularly with the development of hydrogen-based propulsion systems and synthetic fuels (e-fuels), which offer long-term solutions for long-distance and heavy-duty transport. While these areas are less mature compared to road transport, they are gaining momentum due to their high decarbonization potential.

Overall, the findings emphasize the growing complexity of research in this field, which encompasses engineering, energy systems, environmental science, and materials innovation. The global distribution of contributions suggests that international collaboration will continue to shape the evolution of RES applications in transport, with hydrogen and electric mobility technologies remaining key pillars in future research and policy agendas.

Despite significant progress, current research faces several challenges. Data availability and quality remain a major barrier for machine learning applications, limiting model accuracy and generalizability. Infrastructure costs for hydrogen and EV systems are still high, particularly in developing countries, which slows down large-scale deployment. From a modeling perspective, approaches like MILP and dynamic programming are computationally demanding, reducing their scalability for real-time applications.

Additionally, integration with existing power grids and the lack of universal regulatory standards for alternative fuels hinder broader adoption. These limitations underline the need for robust, scalable, and context-sensitive modeling approaches, as well as for interdisciplinary collaboration and policy alignment.

5. Conclusions, Proposals, Recommendations

This study provides a systematic bibliometric analysis of the scientific literature on renewable energy sources (RES) in transport. By leveraging data from the Scopus database and applying visualization techniques through VOSviewer, the research identifies key trends, influential countries and institutions, and dominant thematic clusters shaping this rapidly evolving field.

The findings highlight the leading role of China in both research output and international collaboration, while also recognizing growing contributions from other regions such as India and Saudi Arabia. The keyword co-occurrence analysis confirmed that hydrogen technologies, electrification, and biofuels are currently the most prominent research streams supporting transport decarbonization (Guo *et al.,* 2025; Labaran and Masood, 2025). Additionally, the presence of bioenergy and circular economy-related clusters indicates a multidisciplinary approach toward sustainable mobility solutions (Wang *et al.,* 2025; Soni *et al.,* 2025).

The key findings of the analysis indicate that hydrogen technologies, electric vehicles, and biofuels constitute the dominant technological directions within RES and transport research. China stands out as the most productive and influential country, while Europe and the United States form strong collaborative networks. Keyword clustering confirms that decarbonization, energy storage, and circular economy solutions are central themes in recent studies.

One of the major strengths of this bibliometric analysis is its ability to provide a macroscopic view of global research trends, highlighting key contributors and international collaboration patterns, while uncovering thematic structures that can inform future research priorities (Moustafa, 2025; Kumar and Sleiti, 2025).

The study offers a comprehensive baseline for understanding the research landscape of RES in transport (Bueno-Ferrer and De Pablo Valenciano, 2024) and supports evidence-based decision-making for researchers and policymakers aiming to accelerate sustainable mobility transitions (Kim and Park, 2024; Bai and Bai, 2025).

Despite its strengths, this study has several limitations. Firstly, it relies solely on data extracted from the Scopus database, which, while comprehensive, may not capture all relevant publications indexed in other databases such as Web of Science, IEEE Xplore, or Google Scholar. Consequently, the results may underrepresent research from regions or disciplines that are less represented in Scopus.

Secondly, the keyword co-occurrence analysis is based on author-provided keywords, which may vary in quality and specificity. This limitation was particularly evident in the initial clustering, where biomedical and materials science terms appeared, suggesting thematic noise beyond the transport-oriented scope.

Finally, the study provides a primarily quantitative perspective; further qualitative content analysis of highly cited papers could offer additional insights into conceptual frameworks and methodological approaches within this field.

Despite the growing volume of publications, certain research areas remain underexplored. These include the application of RES in maritime and rail transport, integration with smart grid systems, and modeling of closed-loop resource cycles. Additionally, few studies focus on the interplay between renewable transport energy and infrastructure resilience, or on long-term economic viability of emerging fuel systems such as e-fuels.

This bibliometric study maps the evolving research landscape of renewable energy sources in transportation. It highlights global collaboration trends, thematic emphases on hydrogen and electric mobility, and the rising engagement of emerging economies.

While China leads in both productivity and influence, regions like India and Saudi Arabia are increasing their presence. The analysis also shows the importance of system-level integration studies, particularly regarding fuel technologies and infrastructure.

Future research should expand the database scope beyond Scopus, apply longitudinal trend analyses, and integrate expert assessments for qualitative depth.

Additionally, thematic gaps-such as solar energy in maritime transport or electrification in rural logistics-should be addressed to broaden the relevance of RES strategies across transport sub-sectors.

It should be noted that transport is developing very rapidly and dynamically, in different directions (Guzanek, 2023). Future research should address these limitations by combining data from multiple bibliographic databases, performing deeper citation network analyses to trace the evolution of influential works, and applying longitudinal approaches to track thematic shifts over time. Additionally, integrating expert assessments could enhance the interpretation of thematic clusters and provide a more nuanced understanding of knowledge gaps and research opportunities.

Future research on renewable energy in transport is likely to benefit from the integration of advanced technologies and system-level approaches. Emerging themes such as digital twins for real-time simulation of transport-energy systems, smart grid integration of electric vehicles, and circular economy models-including battery recycling and sustainable fuel cycles-are gaining increasing attention. Addressing these areas will be crucial for designing resilient, intelligent, and sustainable transport systems.

References:

Adamiak, B., Andrych-Zalewska, M., Merkisz, J., Chłopek, Z. 2025. The Uniqueness of Pollutant Emission and Fuel Consumption Test Results for Road Vehicles Tested on a Chassis Dynamometer. Eksploatacja i Niezawodność – Maintenance and Reliability, 27(1). https://doi.org/10.17531/ein/195747.

Ajanovic, A., Haas, R. 2021. Renewable Energy Systems Implementation in Road Transport: Prospects and Impediments. Renewable Energy. Environment and Sustainability, 6, 37. https://doi.org/10.1051/rees/2021034.

Aloi, A., Alonso, B., Benavente, J., Cordera, R., González, F., Ladisa, C., Roumboutsos, A. 2021. Factors Influencing the Adoption of Ride-Sharing Platforms: A Systematic Review. European Transport Research Review, 13, 1-20. https://doi.org/10.1186/s12544-021-00522-1.

Andrych-Zalewska, M., Chłopek, Z., Merkisz, J., Pielecha, J. 2024. Research on the Results of the WLTP Procedure for a Passenger Vehicle. Eksploatacja i Niezawodność – Maintenance and Reliability, 26(1). https://doi.org/10.17531/ein/176112.

Angelico, R., Giametta, F., Bianchi, B., et al. 2025. Green Hydrogen for Energy Transition: A Critical Perspective. Energies, 18, 4567. https://doi.org/10.3390/en18094567.

Azadmanesh, J., Slobodnik, K., Struble, L.R., Lovelace, J.J., Cone, E.A., Dasgupta, M., et al. 2025. The Role of Tyr34 in Proton Coupled Electron Transfer and Product Inhibition of Manganese Superoxide Dismutase. Nature Communications. https://doi.org/s41467-025-57180-3.

Bai, J., Yan, Y., Bai, X. 2025. A Comprehensive Review of Ship Emission Reduction Technologies for Sustainable Maritime Transport. Frontiers in Marine Science, 12, 1576661. https://doi.org/10.3389/fmars.2025.1576661.

Begum, B., Jena, N.K., Sahu, B.K., Bajaj, M., Blazek, V., Prokop, L. 2025. Frequency Stability Improvement in EV-Integrated Power Systems Using Optimized Fuzzy-Sliding Mode Control and Real-Time Validation. Scientific Reports, 15, 1-13. https://doi.org/10.1038/s41598-025-89025-w.

Berdiyorov, G.R. 2025. Influence of Pyridinic Nitrogen on Tautomeric Shifts and Charge Transport in Single Molecule Keto Enol Equilibria. Scientific Reports. https://doi.org/10.1038/s41598-024-81220-5.

Bjerregaard, J.D., Votsmeier, M., Grönbeck, H. 2025. Influence of Aluminium Distribution on the Diffusion Mechanisms and Pairing of $[Cu(NH_3)_2]+$ Complexes in Cu-CHA. Nature Communications, 16, 1-10. https://doi.org/10.1038/s41467-025-55859-1.

Bukhari, M.A., Bukhari, S.M.Z.S., Khan, M.I. 2025. Efficient Photocatalytic Degradation of Industrial Dyes Using $SnWO_4$ for Wastewater Treatment. Next Materials. https://doi.org/10.1016/j.nxmate.2025.100578.

Bueno-Ferrer, Á., De Pablo Valenciano, J. 2024. Unveiling the Potential of Metaheuristics in Transportation: A Path Towards Efficiency, Optimization, and Intelligent Management. Infrastructures, 10, 4. https://doi.org/10.3390/infrastructures10010004.

Carrascal-Hernández, D.C., Grande-Tovar, C.D. 2025. CO2 Capture: A Comprehensive Review and Bibliometric Analysis of Scalable Materials and Sustainable Solutions. Molecules, 30, 563. https://doi.org/10.3390/molecules30030563.

Chatterjee, S., Das, A., Datta, P., Thomas, S., Ghosal, K. 2025. Medium Molecular Weight Chitosan and Magnetite-Based Bead as a Nanocomposite for Drug Delivery: Development and Biocompatibility. International Journal of Biological Macromolecules. https://doi.org/10.1016/j.ijbiomac.2024.139246.

Chen, Q., Wang, J. 2025. Integrated Multi-Energy Hub Optimization: A Model for Reliable,

Economically Efficient, and Sustainable Energy Systems. Eksploatacja i Niezawodność – Maintenance and Reliability. https://doi.org/10.17531/ein/201335.

Fahimnia, B., Sarkis, J., Davarzani, H., Banomyong, R. 2015. Green Supply Chain Management: A Review and Bibliometric Analysis. Transportation Research Part E: Logistics and Transportation Review, 74, 1-22. https://doi.org/10.1016/j.tre.2014.10.00.

Ghaedi, M., Gholami, R. 2025. Characterization and Assessment of Hydrogen Leakage Mechanisms in Salt Caverns. Scientific Reports. https://doi.org/10.1038/s41598-024-84505-x.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M.D., Wagner, N., Gorini, R. 2019. The Role of Renewable Energy in the Global Energy Transformation. Energy Strategy Reviews, 24, 38-50. https://doi.org/10.1016/j.esr.2019.01.006.

Gonda, I., Sorrentino, S., Galazzo, L., Lichti, N.P., Arnold, F.M., Mehdipour, A.R., et al. 2025. The Mycobacterial ABC Transporter IrtAB Employs a Membrane-Facing Crevice for Siderophore-Mediated Iron Uptake. Nature Communications. https://doi.org/s41467-024-55136-7.

Guo, S., Yu, M., Lee, J.K., Qiu, M., Yuan, D., Hu, Z., et al. 2025. Separating Nanobubble Nucleation for Transfer-Resistance-Free Electrocatalysis. Nature Communications, 16, 1-11. https://doi.org/10.1038/s41467-024-55750-5.

Guzanek, P. 2023. Trendy w rozwoju transport - zastosowania metod uczenia maszynowego. In: R. Parczewski (Ed.), Wybrane elementy bezpieczeństwa państwa - rola i zadania transportu, 165-176.

Jaroń, A., Borucka, A. 2024. Analysis of Energy System Transformations in the European Union. Energies, 17(23), 6181. https://doi.org/10.3390/en17236181.

Kim, M.K., Park, M.J. 2024. Exploring and Comparing the Knowledge Structures, Collaborations and Key Themes of Electric Vehicle Research in the Environment Domain. International Journal of Sustainable Transportation, in press. https://doi.org/10.1080/15568318.2024.2448002.

Kumar, L., Sleiti, A.K. 2025. A Comprehensive Review of Hydrogen Safety Through a Metadata Analysis Framework. Renewable and Sustainable Energy Reviews, 188, 113308. https://doi.org/10.1016/j.rser.2025.11330.

Labaran, M.J., Masood, T. 2025. Technological Frontiers: Addressing Renewable Energy Supply Chain and Sustainability Challenges. Discover Sustainability, 6, 58. https://doi.org/10.1038/s43621-025-00909-3.

Lee, J., Shin, Y., Ryu, H., Boo, C., Hong, S. 2025. Toward Zero Liquid Discharge Treatment of Semiconductor Wastewaters with a Hybrid System Integrating Forward Osmosis and Nanofiltration. Water Research. https://doi.org/10.1016/j.watres.2025.12341.

Lei, L., Chen, X., Long, X., Tu, Q., Zhao, L., Huang, D., et al. 2025. Z/Ce@Hemin Enzymes with Enhanced Peroxidase Activity for Monitoring and Screening the Oxidative Stress Models of Parkinson's Disease. NPJ Parkinson's Disease, 11, 1-9. https://doi.org/10.1038/s41531-025-00875-7.

Lindstad, E., Watkins, C.A., Strømman, A.H. 2023. Wise Use of Renewable Energy in Transport. Renewable and Sustainable Energy Reviews, 169, 112927. https://doi.org/10.1016/j.rser.2022.112927.

Li, H., Liu, Y., Zhang, S., Ma, L., Zeng, Z., Zhou, Z., et al. 2025. Access to N-α-Deuterated Amino Acids and DNA Conjugates via Ca(II)-HFIP-Mediated Reductive Deutero-Amidation of α-Oxo-Carbonyl Compounds. Nature Communications. https://doi.org/s41467-025-57098-w.

Li, X., Zhou, Y., Yue, J., Sun, M., Lei, X., Li, P., et al. 2025. Enzyme Mimics Based on

Peptide–Graphene Oxide Assemblies for PET Degradation. Colloids and Surfaces B: Biointerfaces. https://doi.org/10.1016/j.colsurfb.2025.114588.

Liziczai, M., Fuchs, A., Manatschal, C., Dutzler, R. 2025. Structural Basis for Metal Ion Transport by the Human SLC11 Proteins DMT1 and NRAMP1. Nature Communications. https://doi.org/s41467-024-54705-0.

Lower, L., Qiu, Y., Sartor, R.C., Sagues, W.J., Cheng, J.J. 2025. Kinetic Modeling of Thermophilic Anaerobic Digestion of Lemnaceae for Biogas Production. Bioenergy Research, 18, 245-260. https://doi.org/10.1007/s12155-025-10824-0.

Mendoza, C., Arias, S., Botero, M.L., Agudelo, J.R. 2025. Hazardous Gas Emissions from Drop-In Biofuels: Mutagenicity, Cytotoxicity, and Unregulated Pollutants. Journal of Hazardous Materials. https://doi.org/10.1016/j.jhazmat.2024.13669.

Mizuno, H., Tanahashi, K., Takashima, T., Oozeki, T. 2025. Potential Benefit and Challenge Analysis of Photovoltaic-Integrated Electric Vehicles Applied in Merchandise Delivery Services: A Case Study. Renewable Energy Focus. https://doi.org/10.1016/j.ref.2025.100692.

More, G.K., Nkobole, N., Twala, C., Machedi, S., Moswetsa, T.A., Chokwe, R.C. 2025. Evaluation of Antidiabetic and Cytotoxic Potential of Ipomoea spp.: Biochemical and Phytochemical Analysis. Phytomedicine Plus. https://doi.org/10.1016/j.phyplu.2025.100735.

Mostek-Majewska, A., Bossowska-Nowicka, M., Słowińska, M., Ciereszko, A. 2025. PRDX5 and PRDX6 Translocation and Oligomerization in Bull Sperm: A Response to Cryopreservation-Induced Oxidative Stress. Cell Communication and Signaling. https://doi.org/10.12964-024-02015-9.

Moustafa, A.M. 2025. A Three Decade Review of Environmentally Friendly Vehicles Sustainable Development Research. Sustainable Futures, 7, 100201. https://doi.org/10.1016/j.sftr.2025.100201.

Roberto, F.S.J., Ribeiro, J.B., Durães, L. 2025. e-Fuel Production Process Technologies and Trends: A Bibliometric-Based Review. Energy Reports, 11, 445-460. https://doi.org/10.1016/j.egyr.2025.03.005.

Sayeed, M.A., Manikandan, K. 2024. Smart Integration of Renewable Energy into Transportation: Challenges, Innovations, and Future Research Directions. Journal of Renewable Energies, 27, 319-337. https://www.researchgate.net/publication/387493202.

Sinha, A., Shahbaz, M. 2022. Does Green Energy Consumption in the Transport Sector Matter? Evidence from Quantile-on-Quantile Regression Approach. Environmental Science and Pollution Research, 29, 25100-25115. https://doi.org/10.1007/s11356-022-25100-3.

Soni, R., Dvivedi, A., Kumar, P. 2025. Carbon Neutrality in Transportation: In the Context of Renewable Sources. International Journal of Sustainable Transportation. https://doi.org/10.1080/15568318.2024.2447999.

Wang, P., Pei, A., Chen, Z., Sun, P., Hu, C., Wang, X., et al. 2025. Integrated System for Electrolyte Recovery, Product Separation, and CO_2 Capture in CO_2 Reduction. Nature Communications, 16, 1-8. https://doi.org/10.1038/s41467-025-56111-6.

Xu, Z., Liu, Y., Cheng, X., Shang, Y., Wang, Y., Wang, J., et al. 2025. A Catalyst-Coated Diaphragm Assembly to Improve the Performance and Energy Efficiency of Alkaline Water Electrolysers. Communications Engineering. https://doi.org/10.44172-025-00344-2.

Zenhom, Z.M., Abdel Aleem, S.H.E., Zahab, E.A., Boghdady, T.A. 2025. Simultaneous Distributed Generation and Electric Vehicles Hosting Capacity Enhancement

Through a Synergetic Hierarchical Bi-Level Optimization Approach. Scientific Reports. https://doi.org/10.1038/s41598-025-88635-8.

Zhang, J., Liu, Y., Dittrich, T., Wang, Z., Ji, P., Li, M., et al. 2025. Unveiling Charge Utilization Mechanisms in Ferroelectric for Water Splitting. Nature Communications. https://doi.org/s41467-025-56359-y.

Zhang, W., Guhathakurta, S., Khalil, E.B. 2023. The Impact of Autonomous Vehicles on Public Transport Ridership: Insights from the Literature and Future Research Directions. Sustainable Cities and Society, 96, 104613. https://doi.org/10.1016/j.scs.2023.104613.

Zhang, X., Wang, Z., Guo, X. 2025. Confinement-Induced Ni-Based MOF Formed on Ti_3C_2Tx MXene Support for Enhanced Capacitive Deionization of Chromium(VI). Scientific Reports, 15, 1-12. https://doi.org/10.1038/s41598-025-87642-z.

Zhang, Z., Feng, Y., Ding, J., Ma, Q., Zhang, H., Zhang, J., et al. 2025. Rationally Designed Universal Passivator for High-Performance Single-Junction and Tandem Perovskite Solar Cells. Nature Communications, 16, 1-9. https://doi.org/10.1038/s41467-025-56068-6.

Zhang, Z.Q., Duan, P.J., Zheng, J.X., Xie, Y.Q., Bai, C.W., Sun, Y.J., et al. 2025. Nano-Island-Encapsulated Cobalt Single-Atom Catalysts for Breaking Activity-Stability Trade-Off in Fenton-Like Reactions. Nature Communications, 16, 1-10. https://doi.org/10.1038/s41467-024-55622-y.

Zuo, J., Zhao, Z.Y., Zhang, Y., Zillante, G. 2021. Urban Sustainability Assessment Frameworks: A Systematic Review. Transport Reviews, 41, 610-635. https://doi.org/10.1080/01441647.2021.1879309.