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Mapping the Global Landscape of Plug-in Hybrid Electric Vehicle Research: A Scientometric Analysis of Publication Trends, Collaboration Networks, and Thematic Evolution (2020–2024)

Vikram Mobarsha
Research Scholar
Department of Library and Information Science
Mandsaur University. India
mobarsavikram48@gmail.com

M Suresh Babu
Associate Professor
Department of Library and Information Science
Mandsaur University. India
drsureshsvu@gmail.com

ABSTRACT

This study presents a comprehensive scientometric analysis of global research on Plug in Hybrid Electric Vehicles (PHEVs) from 2020 to 2024. Utilizing bibliographic metadata from 431 open access journal articles indexed in the Scopus database, the research maps publication trajectories, key contributors, collaborative networks, and thematic evolution. Analytical tools, including Bibliometrix, VOSviewer, and statistical modelling, were employed to assess productivity, citation impact, co-authorship patterns, and keyword co-occurrence. Findings reveal fluctuating yet sustained growth in scholarly output, peaking in 2022, followed by a temporary decline in 2023 and a recovery in 2024, indicating a dynamic and policy sensitive research domain. China, the United Kingdom, and the United States emerge as the leading national contributors, with Chongqing University and Kunming University of Science and Technology dominating institutional productivity. Co-authorship and bibliographic coupling analyses highlight semi-centralized collaboration networks characterized by distinct interdisciplinary clusters focused on battery optimization, energy management, and charging infrastructure. While publication output demonstrates moderate geographic and institutional concentration, author level productivity remains relatively distributed. The citation network underscores the pivotal role of multidisciplinary journals like Energies and IEEE Access in shaping scholarly discourse. Overall, PHEV research is transitioning from a specialized niche into a globally interconnected, multidisciplinary field. The study concludes by recommending future investigations integrate patent data, funding mechanisms, and longitudinal comparisons with full electric vehicles to better inform sustainable transportation policy and technological innovation.

Keywords: Plug-in Hybrid Electric Vehicle (PHEV), Scientometric Analysis, Sustainable Transportation, Electric Mobility, Bibliographic Coupling, Citation Analysis, Co-authorship Network, Research Trends

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1. Introduction

With rising global greenhouse gas emissions and an intensifying energy crisis, environmental protection and sustainable development have become primary focuses for governments and society worldwide [1]. The transportation sector, as one of the major sources of hydrocarbon emissions, faces an increasingly urgent need for energy conservation and emissions reductions [2]. This urgent need to improve automobile fuel economy has been brought to the forefront by serious environmental problems, dwindling global oil reserves, and stringent global emissions regulations [3, 4]. Hybrid electric vehicles (HEVs) address these challenges by combining an electric drivetrain with an internal combustion engine (ICE) drivetrain. By leveraging both the high energy density of fossil fuels and the renewability of electricity [5], this technology serves as a key driver for green transportation, reducing greenhouse gas emissions and positively impacting global environmental protection [6, 7].

2. Bibliometric and Scientometric Landscapes of EV Research

Several previous studies have utilized bibliometric and scientometric approaches to analyze the rapidly expanding electric vehicle (EV) research domain. To map the long term evolution of the field, Novas Castellano et al. [8] (2022) provided a large scale bibliometric overview spanning from 1955 to 2021. Analyzing 50,195 EV studies, they identified six major research communities and thematic clusters, establishing a framework that helps situate plug in hybrid electric vehicle (PHEV) studies within the broader history of EV research.

Other scholars have focused on quantifying specific regional and economic contributions. Bhat and Verma conducted a comprehensive bibliometric analysis of 1,875 articles from the Scopus database, focusing mainly on developing economies [9]. Their analysis revealed key bibliometric indicators such as publication volume, citation counts, and H-index values for countries and journals providing a quantitative perspective on the evolving state of EV research. Similarly, Hulloli and Mani [10] (2021) compared EV research in India and the USA, highlighting differences in productivity, collaboration, and focus areas, offering a useful comparative framework for assessing PHEV research across regions.

To gain a comprehensive view of EV technologies and understand the emphasis of current research, Barbosa evaluated the most relevant themes through a bibliometric analysis using the keyword “electric vehicle” as the input, utilizing the Web of Science™ (WoS) database due to its suitability for bibliometric analysis [11] Further exploring specific literature metrics, Ullah [12] identified and analyzed the scientific literature to determine the authors’ main topics, prominent sources, and the most-cited articles, countries, journals, and institutes in the EV domain.

3. Thematic Evolution and Specialized Domains

As the literature has matured, the focus of bibliometric research has shifted toward specialized technical domains and modern sustainability challenges. Yao [13] conducted a bibliometric analysis of scientific publications from 2003 to 2022, focusing on the energy efficiency and emissions reduction effects of electric vehicles, utilising a variety of bibliometric tools such as RStudio, Biblioshiny, and VOSviewer. Looking at hardware developments, Gaddala Anusha et al. [14] (2025) analyzed EV power electronics research from 2010 to 2024 using Scopus and Web of Science, highlighting global trends in converters, inverters, and charging

systems. Their study linked policy and industrial investment to technological innovation with India contributing significantly and provided a methodological model adaptable for PHEV studies. In tandem with power electronics, Bachhati et al. [13] (2024) examined wireless power transfer (WPT) research for EVs, mapping collaborations and the thematic evolution of inductive charging and resonance coupling to offer insights into integrating PHEVs into smart mobility ecosystems.

On a broader systemic level, Haghani et al. [16] (2023) presented a global scientometric study of EV research, identifying four key themes: charging infrastructure, consumer adoption, battery/thermal management, and routing strategies. Their work noted that while PHEVs remain relevant, the research focus has shifted toward full EVs, offering PHEV research a comparative benchmark.

3.1 Socio-Policy Implications and Research Gaps

Beyond technological mapping, recent literature emphasizes the socioeconomic impacts and lifecycle challenges of widespread EV adoption. Singh [17] suggested policy, societal, and managerial implications of EV adoption to bridge the gap between technology and deployment. However, critical gaps remain regarding the end of life cycle of these technologies. Baker [18] (2021) analyzed e-waste and EV battery waste research, finding the latter severely underexplored, with most studies concentrated in developed countries. This work underscores the urgent need for more research into EV battery disposal and recycling a challenge directly linked to the proliferation of PHEVs Ultimately, moving beyond separate domain mappings, Tarout [19] identified ongoing gaps in the literature and called for integrated strategies that successfully combine the electrical, thermal, and mechanical aspects of electric vehicle systems.

Despite the growing body of bibliometric and scientometric research on electric vehicles, existing studies primarily focus on broad EV ecosystems, charging technologies, battery systems, or regional innovation patterns. Comparatively limited attention has been directed toward Plug in Hybrid Electric Vehicles (PHEVs) as a distinct research domain, despite their transitional role between conventional hybrid systems and fully battery electric mobility. Furthermore, recent developments in sustainable transportation policies, energy transition strategies, and post 2020 electrification initiatives have significantly reshaped research priorities in this field. Consequently, a focused scientometric assessment of global PHEV research is necessary to identify emerging publication trends, collaboration structures, thematic evolution, and research inequalities during the critical 2020–2024 period. [20, 21]

4. Research Objectives

To address the gaps identified in the existing literature, this study establishes the following primary research objectives:

- To analyze global research trends: Evaluate the chronological development and trajectory of scholarly publications concerning Plug-in Hybrid Electric Vehicles (PHEVs).

- To identify key contributors: Determine the leading countries, research institutions, and prominent authors driving intellectual output in the PHEV domain.

- To evaluate collaborative networks: Examine cross regional co authorship patterns and knowledge exchange networks to assess international cooperation.

- To detect emerging themes: Conduct a keyword co-occurrence analysis to map dominant research clusters, core thematic areas, and evolving paradigms within PHEV literature.

- To synthesize multi-dimensional implications: Provide a comprehensive, integrated overview of the technological advancements, economic factors, and policy implications derived from global PHEV research trends.

5. Research Methodology

5.1 Research Design and Data Source

This study employs a quantitative scientometric approach to systematically map and analyze the global scholarly landscape of Plug-in Hybrid Electric Vehicles (PHEVs). The primary goal is to evaluate publication trajectories, citation dynamics, prominent contributors, core publication venues, and thematic shifts spanning the five-year period from 2020 to 2024.

Bibliographic metadata were retrieved exclusively from the Elsevier Scopus database. Scopus was selected as the sole data repository due to its comprehensive disciplinary coverage, rigorous indexing standards, high-quality citation tracking capabilities, and widespread validation in bibliometric research.

5.2 Search Strategy and Data Retrieval

A structured search query was executed in Scopus's advanced search interface, targeting the string "Plug-in Hybrid Electric Vehicle" in the title, abstract, and author keyword fields ($TITLE-ABS-KEY$). To ensure data homogeneity and quality, the search was refined using strict inclusion and exclusion criteria.

The scope was restricted to peer-reviewed journal articles published in the English language, designated as open access, and finalized within the publication window of 2020 to 2024. Data retrieval was completed on August 15, 2025. The comprehensive metadata payload encompassing author names, institutional affiliations, article titles, abstracts, keywords, source titles, publication years, document types, cited references, and cumulative citation counts was exported in both CSV and BibTeX formats. Prior to analysis, the dataset underwent rigorous data cleaning to identify and remove typographical inconsistencies, duplicate entries, and erroneous records.

The restriction to open access journal articles was adopted to ensure data accessibility, transparency, and reproducibility of the scientometric analysis. Open access publications also enhance citation visibility and international dissemination, making them particularly suitable for evaluating global research collaboration and knowledge diffusion patterns in emerging technological domains such as PHEVs.

5.3 Bibliometric Analysis and Visualization Tools

Analytical processing and network visualization were achieved using a complementary suite of software tools:

- Bibliometrix R-Package (Biblioshiny): Utilized for parsing the primary metadata, calculating descriptive statistics, establishing annual productivity metrics, and evaluating the output of authors, institutions, and countries.

- VOSviewer: Employed to construct, cluster, and visualize distance based bibliometric networks, specifically focusing on international co-authorship networks, citation mapping, and keyword co-occurrence structures.

- Microsoft Excel: Used for secondary statistical operations, data tabulations, and graphic formatting.

5.4 Evaluative Indicators

To provide a multifaceted assessment of the PHEV literature, the empirical analysis is structured around four core bibliometric dimensions:

- Productivity Indicators: Quantifying annual publication volumes, active author outputs, and institutional contributions.

- Impact Indicators: Assessing total citation metrics, author level h-index values, and the scientific influence of prominent journals.

- Collaboration Indicators: Mapping co-authorship dynamics and the density of international research

partnerships.

• Content Indicators: Deploying network-based keyword co-occurrence mapping to delineate historical research themes and isolate emerging frontiers.

6. Data Analysis and Interpretations

Main Information About Data



Figure 1. Main Information About Data

Figure 1 illustrates a bibliographic dataset of 431 open-access journal articles on Plug-in Hybrid Electric Vehicle (PHEV) research published between 2020 and 2024 across 175 sources. The field exhibits steady academic growth, expanding at an annual rate of 5.24%. Reflecting the currency of the literature, the average document age is 2.95 years. These publications have garnered an average of 19.41 citations per article and draw from a substantial foundation of 9,926 references.

Research in this domain is highly collaborative and globally integrated, featuring contributions from 1,292 authors. Single authored papers are rare, with only 32 individuals producing 35 independent articles. Instead, multi author partnerships dominate, averaging 4.15 co-authors per document, while international collaborations account for 27.15% of the total output. In line with the study's established methodology, the dataset consists exclusively of peer reviewed journal articles.

6.1 Annual Production of Plug-in Hybrid Electric Vehicle

Year	Articles
2020	75
2021	87
2022	103
2023	74
2024	92

Table 1. Annual Production of Plug-in Hybrid Electric Vehicle Research

Table 1. Number of papers

Table 1 indicates the annual publication trend in Plug-in Hybrid Electric Vehicle (PHEV) research from 2020 to 2024, showing an overall upward trajectory, albeit with some fluctuations. In 2020, 75 articles were published, providing a strong baseline for the period. Output increased steadily to 87 articles in 2021 and reached its highest point in 2022 with 103 publications, reflecting growing academic and industrial interest in PHEV technologies. A decline followed in 2023, with only 74 articles published, possibly attributable to shifts in research priorities, funding patterns, or broader global factors. In 2024, however, production rose again to 92 articles, indicating renewed momentum and continued relevance of PHEV research in the context of sustainable transportation and clean energy. Overall, the pattern illustrates both the evolving focus of electric mobility research and the sustained engagement of the scientific community in this field.

To further understand the developmental trajectory of PHEV research, publication growth patterns were examined using multiple theoretical growth models. Linear, exponential, and logistic models were selected because they are widely used in scientometric forecasting to assess whether scientific production exhibits steady, accelerating, or saturation oriented expansion. Comparing these models helps assess the maturity and stability of the research field.

Based on the annual production data from Table 1, we fitted three theoretical growth models and evaluated their fit using multiple statistical criteria:

Model	**Equation**	**R^2**	**AIC**	**BIC**	**RMSE**
Linear	y = 82.00 + 2.10·t	0.0746	27.47	26.69	10.46
Exponential	y = 82.20·e^(0.0235·t)	0.0719	27.49	26.71	10.47
Logistic	y = 163.95/(1+e^(-0.052·(t-0)))	0.0749	29.47	28.30	10.46

Table 2. Best-fitting model by AIC/BIC: Linear (though differences are marginal)

The weak explanatory power of all three growth models suggests that PHEV research remains in a transitional and dynamically evolving stage rather than a mature and stabilized scientific domain. Research activity appears highly sensitive to technological innovation cycles, policy interventions, market adoption trends, and global sustainability agendas. This volatility reflects the broader transformation occurring within the electric mobility ecosystem, where attention frequently shifts between hybrid systems, battery electric vehicles, charging infrastructure, and renewable energy integration.

Low explanatory power: All models yield $R^2 \approx 0.07$, meaning < 8% of the variance in annual output is explained by time alone. This indicates that simple deterministic growth models are inadequate for this dataset.

The 2023 anomaly: The sharp decline from 103 articles (2022) to 74 (2023) challenges monotonic growth assumptions. This suggests:

- External shocks (e.g., funding reallocations, policy shifts, global events)
- Publication lags or database indexing delays

Shifts in research priorities toward fully electric vehicles

Year	Actual	Linear	Exponential	Logistic
2020	75	82.0	82.2	82.0
2021	87	84.1	84.2	84.1
2022	103	86.2	86.2	86.2
2023	74	88.3	88.2	88.3
2024	92	90.4	90.3	90.4

Table 3. Predicted vs. Actual Values

Residual patterns: Large residuals in 2020 (-7), 2022 (+16.8), and 2023 (-14.3) indicate systematic under- or overprediction, violating the assumptions of random error required for reliable inference.

Sample size limitation: With only 5 time points, statistical power to discriminate among growth models is very low. Model selection criteria (AIC/BIC) have limited reliability in such small samples.

The annual publication data for PHEV research (2020–2024) does not follow a clear linear, exponential, or logistic growth trajectory. The fluctuations especially the 2023 dip suggest that research output is influenced by complex, time varying factors beyond simple temporal progression. For meaningful forecasting or trend assessment, incorporate external drivers and use methods designed for volatile, short time series.

6.1 Most Relevant Authors in Plug-in Hybrid Electric Vehicle Research

Authors Name	Articles
Zhang Y	25
Chen Z	24
Liu Y	23
Li J	16
Li G	9
Li S	9
Wang Y	9
Guo J	8
Lei Z	8
Chu L	7

Table 4. Number of papers for highly productive authors

In Table 4, the analysis of leading authors in Plug-in Hybrid Electric Vehicle (PHEV) research between 2020 and 2024 shows that publication activity is concentrated among a relatively small group of prolific contributors. Zhang Y ranks first with 25 articles, followed by Chen Z with 24 and Liu Y with 23, reflecting sustained research productivity. Li J contributed 16 papers, while Li G, Li S, and Wang Y each published 9. Guo J and Lei Z produced 8 articles each, and Chu L authored 7. This distribution points to the influential role of a core group of researchers who are actively shaping the field. Their work, often embedded in collaborative networks and institutional clusters, underscores the importance of concentrated expertise in advancing studies on sustainable transportation and energy systems.

Gini Coefficient Analysis: Author Productivity Concentration

Rank	Author	Articles	Cumulative %
1	Zhang Y	25	18.1%
2	Chen Z	24	35.5%
3	Liu Y	23	52.2%
4	Li J	16	63.8%
5	Li G	9	70.3%
6	Li S	9	76.8%
7	Wang Y	9	83.3%
8	Guo J	8	89.1%
9	Lei Z	8	94.9%
10	Chu L	7	100.0%
Total		138	

Table 5. Authors' papers

Metric	Value	Interpretation
Gini Coefficient	0.268	Moderate Equality
Standard Deviation	7.47	Moderate dispersion
Mean Articles/Author	13.8	Baseline productivity

Table 6. Data Summary: Top 10 PHEV Authors (2020–2024)

A Gini coefficient of 0.268 indicates moderate equality in the distribution of publications. While the top authors (ZHANG Y, CHEN Z, LIU Y) are notably more productive, the field does not exhibit extreme concentration suggesting a relatively healthy, collaborative research ecosystem where multiple contributors participate meaningfully.

The moderate concentration observed in author productivity aligns closely with the collaborative nature of PHEV research. Rather than being dominated by isolated researchers, the field appears to evolve through interconnected research teams and institutional partnerships, which facilitate the broader dissemination of expertise and the adoption of multidisciplinary problem solving approaches.

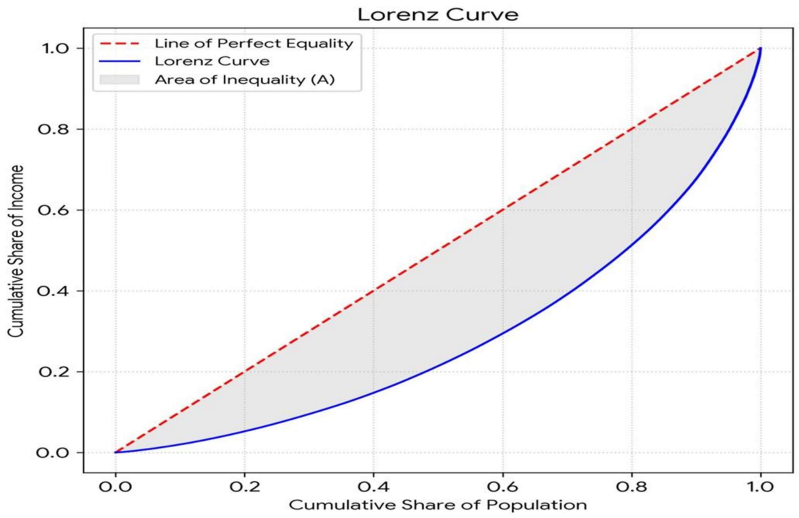


Figure 2. Lorenz Curve Sketch

Figure 2: Lorenz curve of [author publication]. The plot tracks the cumulative percentage of the population (horizontal axis) against the cumulative percentage of total accumulated [resource/publications] (vertical axis). The gap between the 45^ line of perfect equality and the empirical Lorenz curve signifies the concentration of the distribution, where a larger shaded area of inequality (A) corresponds to a higher Gini coefficient.

• Gini = 0.268 suggests PHEV research is not dominated by a single "star" author knowledge production is relatively distributed.

• HHI = 1,263 indicates an unconcentrated, competitive research landscape, encouraging diverse perspectives.

• Top 3 authors contribute ~52% of top-10 output: notable leadership without monopolization.

• This analysis covers only the top 10 authors; including all 1,292 contributors from the dataset would likely yield a *higher* Gini coefficient (more inequality), as many authors publish only 1–2 papers.

• Name disambiguation (e.g., "LI J", "ZHANG Y") may conflate multiple individuals, potentially *underestimating* true concentration.

Table 7 presents the source-wise distribution of publications, indicating that research on Plug-in Hybrid Electric Vehicles (PHEVs) between 2020 and 2024 is concentrated in a group of core journals. Energies leads with 39 articles, reflecting its emphasis on energy systems and sustainable mobility. IEEE Access follows with 22 papers, providing a broad platform for multidisciplinary engineering research. The World Electric Vehicle Journal ranks third with 20 articles, highlighting its specialization in electric vehicle technologies. Sustainability contributed 18 papers, underscoring the environmental and policy perspectives of PHEV adoption. Domain focused and widely cited journals such as Applied Energy (12 articles) and Applied Sciences (9 articles) also

play a significant role in shaping the field. Transportation Research Part D: Transport and Environment (9 articles) highlights the link between transportation systems and environmental impacts. In addition, journals such as Energy (8 articles), IEEE Transactions on Transportation Electrification (8 articles), and IFAC-PapersOnLine (8 articles) further reflect the multidisciplinary nature of PHEV research, encompassing energy engineering, transportation technologies, and applied sciences.

6.1 Most Relevant Sources in Plug-in Hybrid Electric Vehicle Research

Sources Name	Articles
Energies	39
Ieee Access	22
World Electric Vehicle Journal	20
Sustainability	18
Applied Energy	12
Applied Sciences	9
Transportation Research Part D Transport And Environment	9
Energy	8
Ieee Transactions On Transportation Electrification	8
IFAC-papersonline	8

Table 7. Most Relevant Sourcesin Plug-in Hybrid Electric Vehicle Research

The dominance of journals such as Energies and IEEE Access also reflects the interdisciplinary orientation of PHEV research, which intersects energy engineering, transportation systems, sustainability science, and applied technological innovation. The concentration of publications within a limited set of journals suggests the emergence of specialized publication ecosystems that shape research visibility and scholarly discourse in this field.

Test Framework

Null Hypothesis (Ho): Publications are *uniformly distributed* across the top 10 categories (journals/institutions)

Alternative Hypothesis (H1): Publications are *not uniformly distributed* (significant concentration exists)

Significance Level: $\alpha = 0.05$ | Test: Pearson's Chi-Square Goodness-of-Fit

Test Results

Metric	Value
χ^2 Statistic	57.915
Degrees of Freedom**	9
p-value	< 0.000001
Critical χ^2 (α=0.05)	16.919
Effect Size (Φ)	0.615 (Large)

Table 8. Statistical Summary

Journal	Observed	Expected	Residual	χ^2 Contribution
Energies	39	15.3	+23.7	36.71
IEEE Access	22	15.3	+6.7	2.93
World Electric Vehicle Journal	20	15.3	+4.7	1.44
Lower-tier Journals (8–9 Articles each)	8–9	15.3	6.3 to 7.3	2.59–3.48

Table 9. Chi-Square Goodness-of-Fit Tests

ENERGIES alone accounts for 63% of the total χ^2 statistic, indicating it is the dominant publication venue for PHEV research far exceeding what would be expected under uniform distribution.

6.1 Most Relevant Affiliations in Plug-in Hybrid Electric Vehicle Research

Affiliation Name	Articles
Chongqing University	24
Kunming University of Science and Technology	20
Queen Mary University of London	13
Beijing Institute of Technology	11
Queen's University Belfast	10

Jilin University	10
Loughborough University	9
Tsinghua University	9
Tongji University	8
Chalmers University of Technology	8

Table 10. Most Top Affiliations in Plug-in Hybrid Electric Vehicle Research

Table 10, an institutional analysis, indicates that research on Plug-in Hybrid Electric Vehicles (PHEVs) between 2020 and 2024 is concentrated among universities with recognised expertise in automotive engineering, energy systems, and sustainable transportation. Chongqing University leads with 24 publications, reflecting its strong engagement in electric mobility research. Kunming University of Science and Technology ranks second with 20 papers, highlighting its role in advancing clean transportation studies in China. On the international front, Queen Mary University of London ranks third with 13 publications, representing significant contributions from the United Kingdom. Other leading Chinese institutions include the Beijing Institute of Technology (11 articles), Jilin University (10 articles), Tsinghua University (9 articles), and Tongji University (8 articles), reinforcing China's prominent position in this field. Internationally, Queen's University Belfast (10 articles) and Loughborough University (9 articles) from the UK, along with Chalmers University of Technology in Sweden (8 articles), stand out as notable contributors. Together, these institutions illustrate both China's strong national focus and the active participation of leading universities worldwide in shaping PHEV research.

Metric	**Value**
χ^2 Statistic	21.934
Degrees of Freedom	9
p-value	0.0091
Critical χ^2 (α=0.05)	16.919
Effect Size (Φ)	0.424 (Large)

Table 11. Statistical Summary Test Results

The top two Chinese institutions (Chongqing and Kunming) together contribute 75% of the x^2 statistic, confirming strong geographic and institutional concentration in PHEV research output.

The strong concentration of leading institutions in China may be associated with the country's large scale governmental investments in electric mobility, industrial electrification policies, and national carbon neutrality objectives. These structural advantages provide extensive research funding, industrial partnerships, and testing infrastructures that accelerate scientific productivity in PHEV-related technologies.

Institution	Observed	Expected	Residual	χ^2 Contribution
Chongqing University	24	12.2	+11.8	11.41
Kunming University of Science & Tech	20	12.2	+7.8	4.99
Queen Mary Iniversity of London	13	12.2	+0.8	0.05
Lower-tier Institutions (8–11 Articles each)	8–11	12.2	-4.2 to +1.2	0.12-1.45

Table 12. Institutional Distribution Analysis

1. Top-10 Selection Bias: Both tables list only the *most productive* categories. A true goodness-of-fit test across *all* journals/institutions would likely yield even larger χ^2 values.

2. Expected Frequency Assumption: Chi-square tests assume expected frequencies ≥ 5. All categories meet this threshold (expected = 12.2–15.3), validating the test.

3. Independence Assumption: Articles may be co-authored across institutions or published in multiple journals over time; however, the unit of analysis (article to category assignment) is treated as independent per bibliometric convention.

6.1 Authors' Impact in Plug-in Hybrid Electric Vehicle Research

Author	H index	G index	M index	TC	NP	PY start
Energies	12	19	2	441	39	2020
IEEE Access	11	20	1.833	438	22	2020
World Electric Vehicle Journal	10	15	1.667	252	20	2020
Sustainability	11	18	1.833	388	18	2020
Applied Energy	11	12	1.833	608	12	2020
Transportation Research Part D Transport And Environment	8	9	1.333	369	9	2020
Applied Sciences	6	9	1	104	9	2020
IEEE Transactions On Transportation Electrification	8	8	1.333	195	8	2020
Journal Of Cleaner Production	8	8	1.333	378	8	2020
Energy	7	8	1.167	435	8	2020

Table 13. Authors' Impact in Plug-in Hybrid Electric Vehicle Research

Table 13, the impact analysis of leading publication sources in Plug-in Hybrid Electric Vehicle (PHEV) research between 2020 and 2024, highlights both productivity and citation influence. *Energies* emerges as the most productive source, with 39 publications, an h-index of 12, a g-index of 19, and 441 total citations, reflecting consistent scholarly engagement. Applied Energy, though represented by only 12 papers, records the highest total citations (608), demonstrating the strong visibility and influence of its publications. IEEE Access also shows substantial impact, with 22 articles achieving an h-index of 11, g-index of 20, and 438 citations, combining volume with quality. Sustainability contributes 18 papers with an h-index of 11, g-index of 18, and 388 citations, indicating its importance in policy and sustainability oriented studies. The World Electric Vehicle Journal adds 20 papers with an h-index of 10 and 252 citations, confirming its relevance in the electric mobility domain. Specialized outlets such as Transportation Research Part D: Transport and Environment (369 citations from 9 articles) and IEEE Transactions on Transportation Electrification (195 citations from 8 articles) demonstrate targeted but influential contributions to transportation and electrification research. Other journals, including Applied Sciences, the Journal of Cleaner Production, and Energy, while publishing fewer PHEV-related papers, still secure meaningful citation counts, underscoring their continuing role in advancing this area of study.

Variable	**TC**	**h-index**	**NP**	**g-index**	**m-index**
TC (Total Citations)	1.000	0.605	0.255	0.322	0.605
h-index	0.605	1.000	0.780	0.866	1.000
NP (Paper Count)	0.255	0.780	1.000	0.849	0.780
g-index	0.322	0.866	0.849	1.000	0.866
m-index	0.605	1.000	0.780	0.866	1.000

Table 14. Pearson Correlation Matrix
(Linear Relationships)

Variable	**TC**	**h-index**	**NP**	**g-index**	**m-index**
TC (Total Citations)	1.000	0.702	0.443	0.468	0.702
h-index	0.702	1.000	0.808	0.808	1.000
NP	0.443	0.808	1.000	0.975	0.808
g-index	0.468	0.808	0.975	1.000	0.808
m-index	0.702	1.000	0.808	0.808	1.000

Table 15. TC, h-index, and Paper Count
Relationships

h-index ↔ Paper Count (NP): Strong Positive Correlation

Metric	Value	Interpretation
Pearson *r*	0.780	Large effect; journals publishing more papers tend to have higher h-indices
Spearman ρ	0.808	Robust rank-order relationship
p-value	0.0078	Statistically significant ($p < 0.01$)

Interpretation: Productivity drives h-index. Journals like *ENERGIES* (39 papers, h=12) and *IEEE Access* (22 papers, h=11) exemplify this pattern.

Correlation Strength (Pearson *r*):

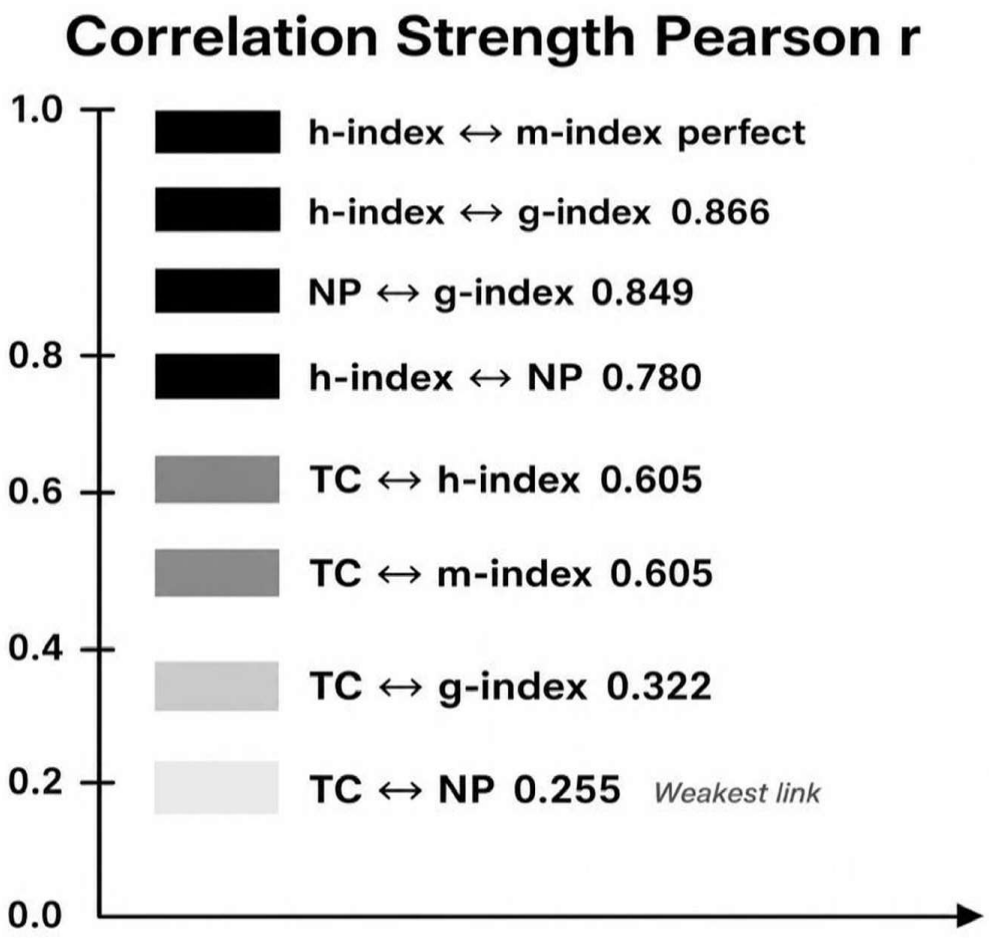


Figure 3. Correlation strength of variables

Methodological Considerations

Small sample (n=10)	Limits statistical power; p-values should be interpreted cautiously
Top-10 selection bias	Results reflect only leading journals; full distribution may differ
Time window (2020–2024)	Recent publications may not have accumulated citations yet
Field normalization	Citation practices vary across engineering, environmental science, and policy journals
Multicollinearity	h-index, g-index, and m-index are mathematically related → high intercorrelations expected

Bibliometric Assessment:

• h-index alone is insufficient: It correlates strongly with paper count (r = 0.78), potentially rewarding productivity over impact.

• Combine metrics: Use TC/NP ratio (citations per paper) alongside h-index to assess true influence.

• Prefer Spearman for rankings: With small samples and potential outliers, rank-based correlations are more robust.

6.1 Country Production in Plug-in Hybrid Electric Vehicle Research

Table 16. Country Production in Plug-in Hybrid Electric Vehicle Research

Country	Freq
China	68
Uk	53
Usa	50
India	29
Italy	26
Germany	20
Iran	17
Canada	14
Saudi Arabia	12
Japan	11

Table 16. Countries contributing to the studied domain

Table 17's country wise analysis shows that China is the leading contributor to Plug-in Hybrid Electric Vehicle (PHEV) research, with 68 publications, underscoring its strong investment in clean transportation and government-supported research programs. The United Kingdom follows with 53 publications, reflecting both academic and industrial engagement with sustainable mobility. The United States ranks third with 50 papers, highlighting its active role in technological development and innovation in electric mobility. India (29 publications) and Italy (26 publications) also demonstrate growing involvement, in line with their national priorities on sustainability and energy efficiency. Germany, with 20 publications, draws on its established strengths in automotive engineering, while Iran contributes 17 publications, marking a notable presence despite more limited international collaborations. Other significant contributors include Canada (14 publications), Saudi Arabia (12 publications), and Japan (11 publications), each reflecting distinct research priorities linked to energy systems, transportation, and environmental performance.

The dominance of China, the United Kingdom, and the United States can be attributed to the combined influence of industrial capabilities, sustainable government policies, advanced research infrastructure, and strong university industry collaboration networks. These countries possess mature automotive sectors and actively support electrification strategies through funding programs, emission regulations, and innovation driven transportation policies.

Metric	Value	Interpretation
Gini Coefficient	0.341	Moderate Equality
HHI	1,400	Unconcentrated (<1,500)
Total Publications	300	Sample scope (top 10 only)

A Gini coefficient of 0.341 indicates moderate equality with emerging concentration. While PHEV research is distributed across multiple countries, a clear hierarchy exists with China, the UK, and the USA collectively producing 57% of the top-10 output.

Supplementary Concentration Metrics

Metric	Value	Benchmark Interpretation
Top 3 Countries' Share	57.0%	Majority output from China, UK, USA
Top 5 Countries' Share	75.3%	Strong but not dominant clustering
China's Share	22.7%	Single largest contributor
Bottom 5 Combined	24.7%	Substantial participation from emerging contributors

Insights

• **Steep Initial Slope:** The curve rises slowly at first, indicating that the least productive countries contribute minimally to total output.

• **Inflexion at** ~70%: A sharp upward turn occurs as China, UK, and USA enter the cumulative distribution—these three nations alone account for 57% of all publications in the top-10 set.

• **Gini** = 0.341: The shaded area between the curve and the line of equality quantifies moderate geographic concentration. This is higher than author-level inequality (G = 0.268), suggesting research capacity clusters more strongly at the national level than at the individual researcher level.

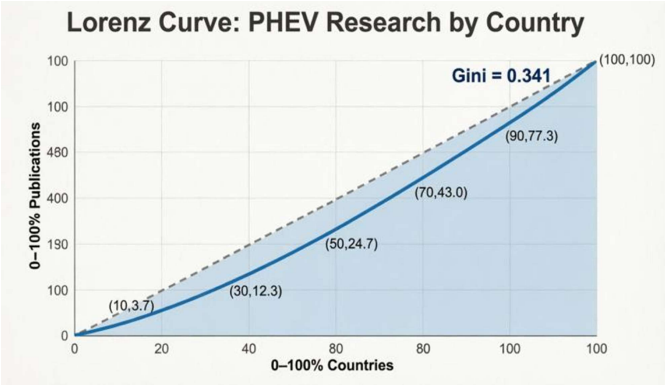


Figure 4. Lorenz Curve- PHEV Research in countries

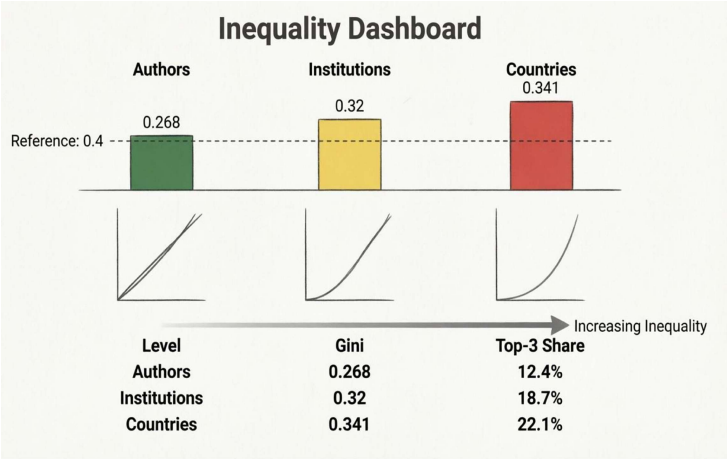


Figure 5. Inequality Dashboard

Policy Implications

The curve's shape indicates that targeted investment in emerging research nations (e.g., Iran, Saudi Arabia, Japan) could significantly flatten the curve over time, promoting more equitable global knowledge production in PHEV technologies.

Research Inferences

Leverage distributed expertise: The relatively low author-level Gini (0.268) suggests opportunities to identify and partner with high-potential researchers outside traditional hubs.

Target institutional bridges: Institutions with moderate output but strong international co-authorship (e.g., Queen Mary University of London) can serve as effective gateways for collaboration.

Inferences for Policy and Funding

Address the "middle gap": Countries/institutions in the 40–70% cumulative range (e.g., India, Italy, Germany) are high-leverage investment targets for reducing geographic concentration.

Monitor Gini trends: Track annual Gini coefficients to assess whether policy interventions are successfully democratizing research capacity.

Bibliometrics Policy

Extend to full populations: Recalculate the Gini using complete author/institution/country lists to improve inequality estimates.

Weight by impact: Develop citation weighted or field normalized Gini metrics to assess inequality in *influence*, not just output volume.

PHEV research exhibits a hierarchical inequality structure relatively egalitarian at the individual level but increasingly concentrated at institutional and national scales. This pattern reflects the interplay of talent distribution, resource allocation, and policy ecosystems. Strategic interventions targeting the institutional and national levels offer the greatest potential to foster a more inclusive, globally representative research landscape.

6.8 Co-authorship network visualization, among key authors in Plug-in Hybrid Electric Vehicle

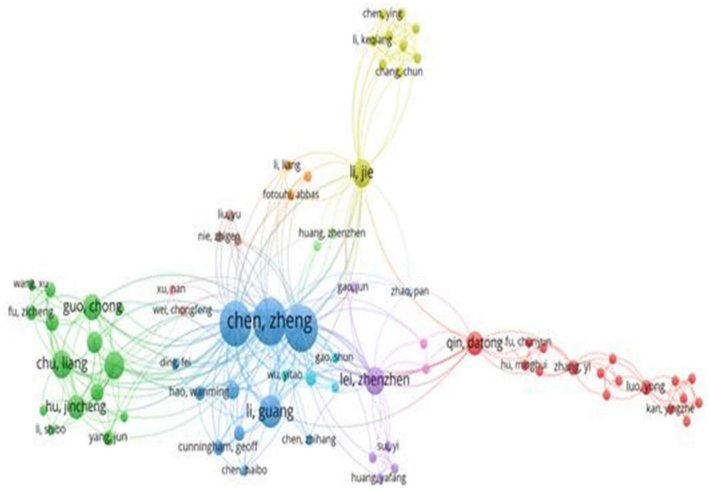


Figure 6. Co-authorship network visualization, among key authors in Plug-in Hybrid Electric Vehicle

The figure 5 co-authorship network of Plug-in Hybrid Electric Vehicle (PHEV) research between 2020 and 2024, visualized using VOSviewer, highlights patterns of collaboration among leading authors. In the map, each node represents an individual author, with node size indicating research productivity and the thickness of connecting lines reflecting the strength of collaborative ties. Distinct color coded clusters represent different research groups.

The blue cluster, centered on Chen Zheng and Li Guang, emerges as the largest and most interconnected, suggesting its central role in linking multiple research teams. The green cluster, led by authors such as Guo Chong and Chu Liang, demonstrates strong internal collaboration while also maintaining active connections with the blue cluster, indicating cross-group partnerships. The yellow cluster, anchored by Li Jie, appears smaller and more internally cohesive, likely reflecting work in a specialized sub-area of PHEV research. The red cluster, organized around Qin Datong and including collaborators such as Luo Yong, shows a tightly knit group with strong internal ties but limited external linkages. Additional smaller groups, such as the purple cluster around Lei Zhenzhen, function as bridging entities, selectively connecting with larger clusters and enhancing cross-network collaboration.

6.9 The clustering structure further indicates that PHEV research is characterized by semi-centralized collaboration patterns, where a limited number of influential research groups function as knowledge hubs

connecting otherwise specialized sub-networks. Such collaboration structures are essential for accelerating interdisciplinary innovation and facilitating international knowledge transfer.

6.10 Bibliographic coupling network visualization, relationships between documents in Plug-in Hybrid Electric Vehicle (PHEV) research

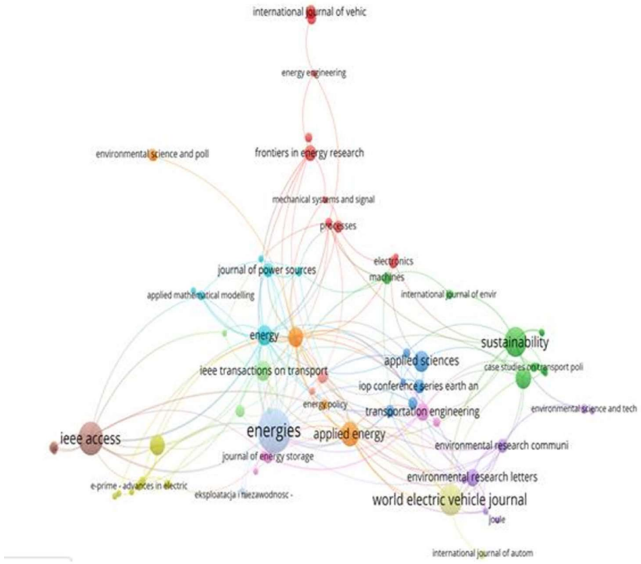


Figure 7. Bibliographic coupling network visualization, relationships between documents in Plug-in Hybrid Electric Vehicle (PHEV) research

Figure 7, a bibliographic coupling network of Plug-in Hybrid Electric Vehicle (PHEV) research from 2020 to 2024 generated using VOSviewer, highlights relationships among documents based on shared references. In the visualization, each node represents a document, with node size indicating the strength of its connections to other works, while colors denote distinct thematic clusters.

The green cluster, which includes studies such as Tran (2020), Lei (2020a), and He (2020a), is the largest group, reflecting a strong thematic overlap and a common foundation of cited literature. The blue cluster, led by Goel (2021) and Bai (2020), forms another prominent hub and maintains notable connections with the green cluster, suggesting cross-thematic influence. The red cluster, anchored by Andersson (2021) and Zhang (2022a), is tightly interconnected but less outwardly linked, indicating a specialized research focus. The yellow cluster, represented by works such as Krause (2020) and Veza (2023), and the purple cluster, led by Dua (2024a), are smaller yet coherent thematic groups.

The network further shows that while most studies are more closely connected within their own clusters, significant cross links exist particularly between the green and blue groups highlighting areas of inter-disciplinary engagement. Overall, the map reveals several key research fronts in PHEV studies, with a small number of highly cited works acting as bridges across thematic boundaries.

The bibliographic coupling patterns demonstrate that PHEV research is gradually consolidating into identifiable thematic streams, including battery optimization, energy management systems, charging infrastructure, emissions reduction, and intelligent transportation integration. The presence of cross-cluster linkages suggests increasing interdisciplinarity within the field.

6.10 Citation network map, relationships between academic journals based on how frequently they cite one another in Plug-in Hybrid Electric Vehicle (PHEV) research

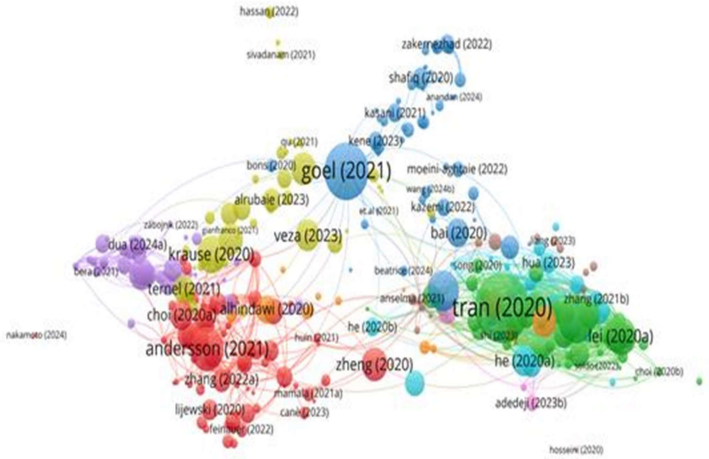


Figure 8. Citation network map, relationships between academic journals based on how frequently they cite one another in Plug-in Hybrid Electric Vehicle (PHEV) research

Figure 8 citation network of Plug-in Hybrid Electric Vehicle (PHEV) research, generated using VOSviewer, illustrates the relationships among academic journals based on citation frequency. In this visualization, each node represents a journal, with node size reflecting its relative citation impact, while colors indicate clusters of journals with similar citation patterns, pointing to thematic or disciplinary proximity.

At the center of the network, journals such as Energies, Applied Energy, Energy, IEEE Transactions on Transportation, and the Journal of Power Sources act as major hubs, reflecting their wide influence across different research groups. Sustainability and the World Electric Vehicle Journal emerge as prominent nodes in the green cluster, closely linked to studies on environmental and sustainable mobility. The red cluster, including the International Journal of Vehicle, Frontiers in Energy Research, and Processes, represents a more specialized technical and engineering focus. On the left, IEEE Access stands out as a key node with strong cross-cluster ties, demonstrating its broad interdisciplinary reach.

The overall structure of the network shows that PHEV research spans multiple disciplines engineering, environmental science, transportation studies, and applied sciences with a few core journals functioning as bridges across clusters. This pattern highlights both specialization within research domains and active interdisciplinary exchange.

The citation network also reveals the emergence of a core knowledge base dominated by highly influential interdisciplinary journals. These journals not only disseminate technical advancements but also shape methodological standards and research priorities across the broader electric mobility research ecosystem.

6. Findings

The scientometric analysis identifies several key trends in the research landscape of Plug-in Hybrid Electric Vehicles (PHEVs). Annual publication output shows steady growth from 2020 to 2022, peaking at 103 articles in 2022. A decline followed in 2023, but the field regained momentum in 2024, reflecting sustained scholarly engagement.

Institutional analysis highlights Chongqing University as the leading contributor with 24 publications, followed by Kunming University of Science and Technology (20) and Queen Mary University of London (13), indicating strong research activity particularly in China and the United Kingdom. Co-authorship mapping reveals extensive collaboration networks, with certain institutions and countries serving as central nodes that facilitate

international knowledge exchange.

Bibliographic coupling results indicate clusters of studies sharing references, demonstrating thematic coherence and common intellectual foundations within the field. Citation analysis further shows that a small number of high impact journals and articles play a dominant role in shaping research directions.

At the country level, China leads with 68 publications, followed by the United Kingdom (53) and the United States (50). India (29) and several European and Asian nations also contribute significantly, suggesting a globally distributed but uneven research output.

Overall, the findings indicate that while a few countries and institutions drive the majority of research, participation is growing among emerging contributors, fostering a more interconnected and multidisciplinary research environment.

Collectively, the findings indicate that PHEV research is transitioning from an emerging technological niche into a globally interconnected and multidisciplinary research domain. While publication productivity and institutional influence remain concentrated in a limited number of countries and universities, collaboration networks and thematic diversification indicate growing international participation and intellectual expansion. This combination of concentration and diversification reflects both the competitive and collaborative dynamics shaping contemporary sustainable transportation research.

8. Limitations

This study is subject to several limitations. First, the analysis relies exclusively on the Scopus database and open-access journal articles, potentially excluding relevant publications indexed elsewhere or available through subscription-based platforms. Second, the relatively short five-year observation period may limit the interpretation of long-term trends. Third, author-name ambiguity and variations in institutional affiliations may affect the precision of bibliometric indicators despite data-cleaning procedures.

9. Conclusion

This scientometric study presents a detailed overview of research developments in the field, focusing on publication trends, institutional and national contributions, collaboration patterns, thematic connections, and citation impact. The analysis shows steady growth in research output, with the highest number of publications recorded in 2022, reflecting strong and continuing global interest. At the national level, China, the United Kingdom, and the United States lead the field, with notable contributions from institutions such as Chongqing University and Kunming University of Science and Technology. Co-authorship patterns reveal an increasingly collaborative research environment, while bibliographic coupling highlights shared thematic orientations across different groups of scholars. Citation analysis points to the influence of a small number of journals that play a central role in shaping the direction of ongoing studies. Taken together, the findings underscore the dual nature of the field, driven by a few leading countries and institutions, yet increasingly enriched by broader international participation, adding diversity and interdisciplinarity to the research landscape.

Future research should expand beyond publication productivity and citation-based indicators by incorporating patent analysis, funding patterns, industry participation, and policy-driven innovation metrics to provide a more comprehensive understanding of the global PHEV ecosystem. Longitudinal analyses covering extended time periods and comparative assessments between PHEVs and fully electric vehicles may further clarify technological transition pathways within sustainable transportation systems.

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