Exploring the Nexus of Electric Vehicles, Environmental Health and Sustainability: A Comprehensive Bibliometric Review

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Electric vehicles, Network analysis, Bibliometric analysis, Sustainability, Scientific mapping.

ABSTRACT
This study analysed 636 papers from the Scopus database using bibliometric and graphical techniques to trace the evolving research on sustainability, environmental health (EH), and electric vehicles (EVs). Research patterns, notable authors, most contributing nations, associations, leading journals, and the most widely referenced publications were all noted. Although the top journals for EV policy research are Sustainability and Journal of Cleaner Production, Sovacool Bk is acknowledged as the most active contributor. The top two contributions are the USA and China, underscoring their vital roles in the creation of EVs and creative policies. The primary contributor to the field research is Tsinghua University. With the maximum citations, the study by Egbue (2012) in Energy Policy suggests a significant long-term influence. The study uses Bradford's Law to confirm that important research is concentrated in specific publications and Lotka's Law to analyse author productivity. The results indicate that certain authors are quite prolific, which are in line with Bradford's Law but not Lotka's Law. The seven thematic clusters that emerged were (a) "Sustainable transportation and policy," (b) "Sustainable mobility and energy," (c) "Environmental Impact and Circular Economy," (d) "Electric Vehicles Adoption and Climate Change," (e) "Battery and Lithium-Ion Technology," (f) "Shared and Connected Mobility," and (g) "Smart Grid and Vehicle-to-Grid Integration." Overall, the study highlights the importance of interdisciplinary EV research as well as the need for infrastructure, regulatory, and technology improvements to support sustainable EV adoption. By employing keyword co-occurrence analysis, the study offers academics and policymakers valuable information, establishing the framework for resolving problems and promoting innovation in the EV ecosystem.

1. Introduction

The development of green and sustainable transportation solutions is urgently needed due to the fast acceleration of climate change and the detrimental effects of conventional cars on the environment. The need to switch to low-emission and energy-efficient modes of transportation is becoming increasingly apparent, as transportation is one of the main sources of greenhouse gas emissions, contributing approximately 14% of global emissions (Intergovernmental Panel on Climate Change (IPCC), 2023). As part of this shift, electric vehicles (EVs) have gained popularity because of their potential to drastically cut the greenhouse gas emissions and air pollutants, which are key contributors to climate change and poor air quality in urban areas (Corr, 1995). Electric cars are at the links of environmental responsibility and technical advancement. Electric vehicles (EVs) have lower direct emissions than conventional internal combustion engine vehicles since they are powered by electricity instead of fossil fuels (Rode et al., 2020). Urban air pollution has been connected to a number of health issues, including cardiovascular and respiratory disorders, as well as early mortality (World Health Organization, 2021). The use of electric vehicles (EVs) may help reduce this pollution. In high-density locations, switching to a fleet of mostly electric vehicles may lower pollution exposure and enhance public health outcomes, per recent studies (Wu et al., 2020; Goodkind et al., 2019). Additionally, EVs support global sustainability objectives, including those set forth in the Sustainable Development Goals (SDGs) of the United Nations, especially Goals 11 and 13, which support sustainable cities and communities and climate action, respectively (Lalitha & Radhakrishnamurty, 1975). The goal of government initiatives like "Startup India" and "Make in India" is to encourage companies that are leading the way in technological innovations like electric cars (Malhan et al., 2021). The move to electric vehicles is seen as a vital step in advancing economic sustainability as well as a remedy for environmental problems. EVs are becoming more widely available due to advancements in battery technology and a decline in production costs, which has accelerated their market penetration worldwide (Bloomberg NEF, 2021). However, obstacles including environmental impact of battery manufacturing, end-of-life disposal, and dependence on energy sources that aren't always renewable underscore how difficult it is to create completely sustainable electric mobility solutions (Zhou et al., 2021). This work offers a bibliometric overview of the body of research at the nexus of sustainability, environmental health, and electric vehicles in light of these complex consequences. This approach not only highlights the most important articles and researchers in the field, but also uncovers new trends, patterns of collaboration, and knowledge gaps. In a field that is changing quickly, bibliometric analysis provides a quantitative method for comprehending research trends, new subjects, and knowledge gaps (Donthu, Kumar, Mukherjee, et al., 2021). This study aims to offer important insights into the direction of EV research, the effects on environmental health, and the sustainability of the EV ecosystem by looking at a large body of literature. By examining important themes, significant authors, and citation networks, this study seeks to present a thorough picture of the state of the field, pinpoint noteworthy research clusters, and offer suggestions for further investigation. This study is focused on examining the following research questions:

RQ1: What are the yearly publication trends in the relevant fields regarding electric vehicles, environment health and sustainability?

RQ2: Who are the most productive authors, countries, affiliation and journals?

RQ3: What are the most relevant keyword clusters?

RQ4: Which are the most well-known publications in the field?

RQ5: Do the study's findings align with Lotka and Bradford's bibliometric laws?

RQ6: What possible avenues for future study exist in the area of electric vehicles, environment health and sustainability?

2. Research Methodology

The study examined publication patterns in the field of electric vehicles, environmental health and sustainability, using a bibliometric approach, concentrating on the most often cited publications, countries, journals, and organizations. According to (Zupic, 2015), the bibliometric method uses a quantitative approach to characterize, evaluate and track published research. It offers a trustworthy and unbiased way to examine the evolution of a certain topic (Giannakis, 2012; Aria & Cuccurullo, 2017). This approach supports future research and provides a clear picture of a field's historical growth, consists of citation analysis, co-citation analysis, co-author analysis, and co-word analysis (Zupic, 2015; Gandia et al., 2019). Bibliometric laws, such as Lotka's law and Bradford's law, are applied in the study to determine the scientific productivity of authors and the core group of journals in the field of study.

2.1 Software used in the Study

The study uses the Bibliometrix R programming package (Aria and Cuccurullo, 2017) and Vosviewer (Van Eck and Waltman, 2014) for analysis. As R is a versatile and extensible programming language with numerous integrated packages and frequent updates, it is particularly helpful for bibliometric research. Analysts and academics use it extensively for statistical computing and visualization (Aria & Cuccurullo, 2017; Forliano et al., 2021). A tool called VOSviewer is well-known for its broad range of analysis and visualization features; it focuses on bibliometric map graphical display, including trend, density, and co-occurrence analysis (van Eck & Waltman, 2010; Ullah et al., 2023). The study's data came from the Scopus database, which was then converted into a bibliometric file and analyzed using R Studio's biblioshiny package and VOSviewer.

2.2 Database, Keywords and Search String

Documents for analysis were gathered for the study using the Scopus database. Web of Science and Scopus are both well-known databases, but this study uses Scopus because it has more journals and is the largest repository of peer-reviewed literature (Bhat & Qureshi, 2023; Maral, 2024; López-Illescas et al., 2008; Kumar et al., 2023; Todorovic, 2023; Solanki et al., 2023; Aghaei Chadegani et al., 2013). Furthermore, a large number of social science researchers have performed review studies using the Scopus database (Donthu et al., 2020; V. Kumar et al., 2021; Dhingra & Batra, 2024; Donthu, Kumar, Pattnaik, et al., 2021; Martı, 2018; Saini, 2023; Sieverts, 2006). On October 28, 2024, a search was carried out to obtain data for the years 2010–2024 from the Scopus database. The search string utilized in the study to retrieve data was (("electric vehicles" AND "environmental health" AND "sustainability")) OR (("electric vehicles" AND "environmental health")) OR (("electric vehicles" AND "sustainability")). It results 3468 documents. We also incorporated inclusion and exclusion criteria into our search results to reduce irrelevant content and maintain consistent data cleanliness. The time frame for the study's execution is the next inclusion criterion. The analysis took into account data from 2010 to 2024. It results

3401 documents, as presented in Figure 1. Further refining the results to the subject categories: "Economics", "Environmental science", "Social science", and "Business, management and accounting" yielded 1,680 documents. Additional refinement was carried out based on language, source type, and document type. As a result, only English-language journal articles that were at the final stage of their publication process, were taken into consideration for inclusion. Books, book chapters, and review articles were not included as they are not regarded as primary sources. It brings 1130 documents as result. 494 articles that were deemed less pertinent for the study were eliminated after each article's full text was examined through the process of manual filtration. It produces 636 papers in all. For the study's analysis and conclusion, these documents were examined using R Biblioshiny and VOSviewer.

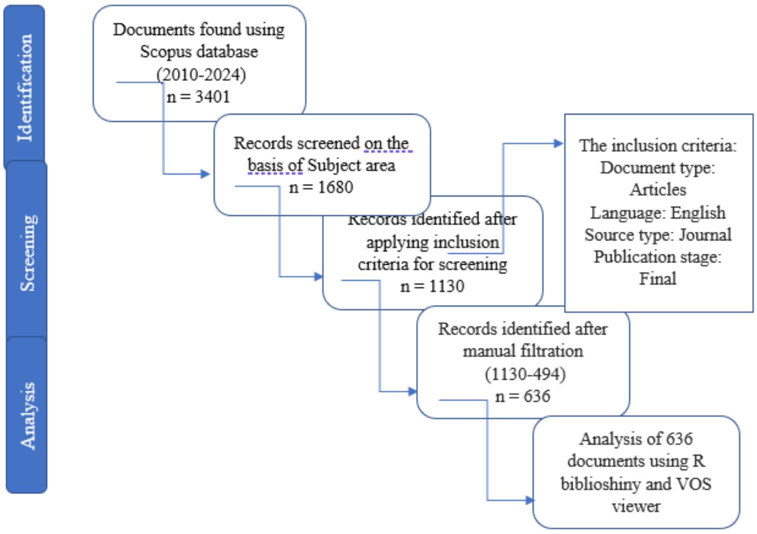

Figure 1. PRISMA framework

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3. Analysis and Results

3.1 Overview of the data

With an annual growth rate of 15.48%, the table 1 compiles the bibliometric information of 636 research papers published from 2010 to 2024, drawn from 144 journals. With an average age of 4.47 years, the documents were referenced 38,466 times, with an average of 52.91 citations per document. The theme focus was reflected in the 2,093 author-specified keywords and 4,044 Keywords Plus that were found through content analysis. With an average of 3.76 co-authors per document and 33.49% international co-authorship, the 2,047 distinct authors and 43 single-authored documents suggest a collaborative atmosphere. The data was compiled by authors and all papers related to electric vehicles, environmental health and sustainability are journal articles.

Table 1. Summary of the data

Description	Results
Main information about data	
Timespan	2010:2024
Sources (Journals, Books, etc)	144
Documents	636
Annual Growth Rate %	15.48
Document Average Age	4.47
Average citations per doc	52.91
References	38466
Document Contents	
Keywords Plus (ID)	4044
Author's Keywords (DE)	2093
Authors	
Authors	2047
Authors of single-authored docs	40
Authors Collaboration	

Single-authored docs	43
Co-Authors per Doc	3.76
International co-authorships %	33.49
Document Types	
article	636

Source: Created by Authors

3.2 Publication Trend

The annual number of articles produced between 2010 and 2024 is depicted in Figure 2. From just two articles in 2010 to a peak of 112 articles in 2021, the pattern demonstrates a consistent rise in publishing articles on the topic. Following this high, there is a minor decline in the number of articles, with 92 in 2022 and 74 in 2023 before a sharp decline to 15 in 2024. This trend points to a gradual increase in interest in the subject over time, followed by a minor drop in recent years, which could be the result of publishing rate saturation or other outside influences.

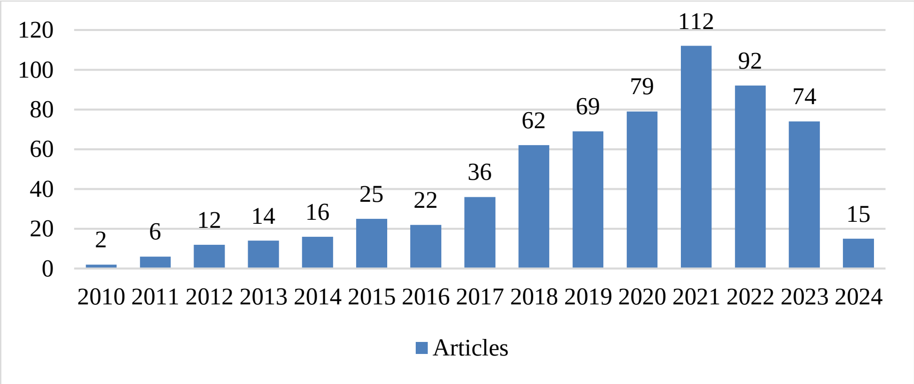

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Figure 2. Annual Publication Trend

3.3 Prominent Sources

The indicators on the number of published articles and total citations (TC) for each academic publication are displayed in the table 2 and Figure 3, which ranks them according to their emphasis on sustainability-related research. With 98 articles and 2,763 citations, Sustainability (Switzerland) journal dominates the sector. The Journal of Cleaner Production comes in second with fewer articles (49), but more citations (3,037), demonstrating a high impact. With about 35 to 45 papers and high citation counts (more than 2,400 per paper), other prestigious journals, such as Transportation Research Part D: Transport and Environment and Applied Energy journal, also exhibit significant engagement, demonstrating their powerful effect. Journals like Technological Forecasting and Social Change and Sustainable Cities and Society publish fewer articles but still have average citation counts, indicating specialized but significant contributions within particular sustainability domains like energy policy, urban development, and technological forecasting.

Table 2: Top 10 most contributing sources

Sources	Articles	TC
Sustainability (Switzerland)	98	2763
Journal of Cleaner Production	49	3037
Transportation Research Part D: Transport and Environment	45	2563
Applied Energy	35	2434
Resources, Conservation and Recycling	24	1860
Sustainable Cities and Society	23	884
Energy	21	1162
Transportation Research Part A: Policy and Practice	20	1155
Energy Policy	18	2625
Technological Forecasting and Social Change	13	463

Source: Created by Authors

Legend: TC = Total Citations

Source: Created by Authors

Figure 3. Most productive sources

3.4 Most contributing Authors

The information given in table 3 includes a list of authors, their total citations (TC), and the number of publications. Figure 4 graphically presents the most productive authors in the field. With 13 articles and 982 citations, SOVACOOL BK is the prominent in their field, demonstrating both great output and influence. With seven publications each and an identical number of citations (724), KUCUKVAR M and ONAT NC most likely worked together on high-impact projects. ZHANG Y comes next, with seven publications but a lower total of 397 citations. Different citation counts for authors such as DEVECI M, LI J, and TATARI O, who have each written six publications, indicate that the effect of each article varies. Compared to others with comparable publication counts, TATARI O has a significantly higher citation count (659) than the other members of this group, suggesting a significant research influence. With five publications apiece, KESTER J and LI Y complete the list with 329 and 209 citations, respectively. While others exhibit varying degrees of influence, SOVACOOL BK and TATARI O stand out for their citation impact overall.

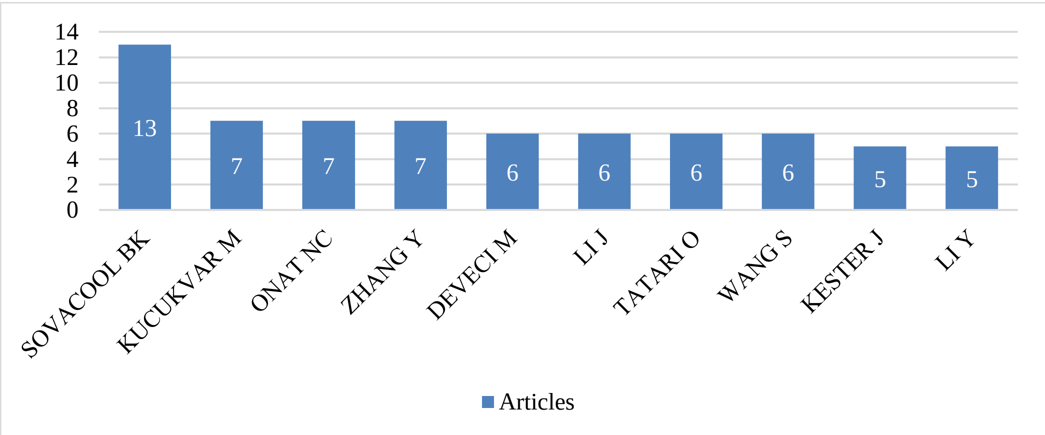

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Figure 4. Most productive authors

Table 3: Top 10 most prominent authors by articles and citations

Authors	Articles	TC
SOVACOOL BK	13	982
KUCUKVAR M	7	724
ONAT NC	7	724
ZHANG Y	7	397
DEVECI M	6	314
LI J	6	381
TATARI O	6	659
WANG S	6	284
KESTER J	5	329

LI Y	5	209

Source: Created by Authors

3.5 Lotka's Law

Lotka's law (Lotka, 1926), a bibliometric law applied in this study, describes the distribution of papers authored in a certain field of study. According to this law, 60% of authors in a particular field of study have only one publication, 15% have two, and 6.6% have three (Wang et al., 2022; Tepe et al., 2022). The percentage of writers according to the quantity of publications is displayed in Table 4. According to the data, 89.4% of the authors generated just one article, which is significantly less than the 60% necessary under Lotka's law. 2.3% of authors have produced three articles, which is also below the legal standard of 6.6%, and 7.08% of authors have written two articles, which is significantly less than the 15% criterion. Figure 5 shows the difference between the observed distribution and Lotka's distribution. In the graphic, the dashed line shows the theoretical distribution according to Lotka's law, whereas the solid line reflects the actual observed data. A significant portion of authors only contribute one or two articles, while a far smaller fraction contributes more than two publications, as seen by the graph's dramatic drop-off around the origin. According to the findings, authors' research in the domains of EVs, EH and Sustainability, departs from Lotka's law.

Table 4: Distribution of authors based on publications

No. of Articles	No. of Authors	Frequency
1	1831	0.89447973
2	145	0.07083537
3	48	0.02344895
4	8	0.00390816
5	7	0.00341964
6	4	0.00195408
7	3	0.00146556
13	1	0.00048852

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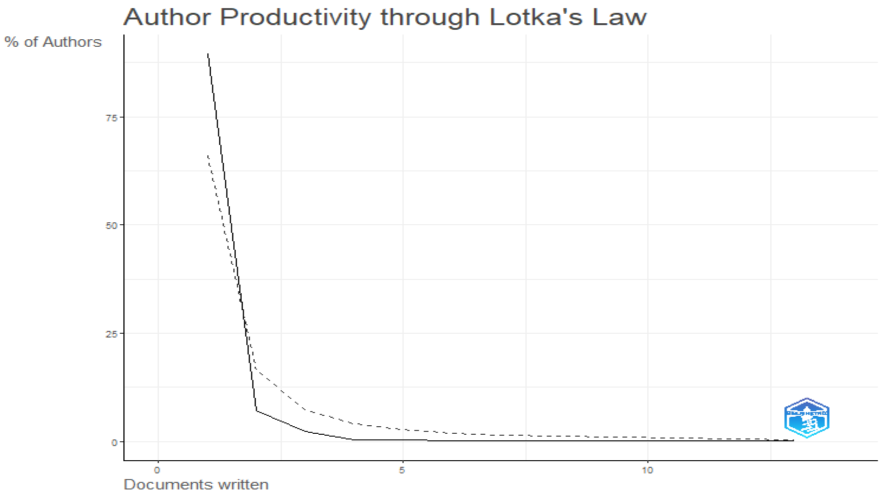

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Figure 5. Observed distribution vs. Lotka's law distribution

3.6 Bradford's Law

Bradford's law (Geophysics, 1985) determined the primary sources for a given topic and evaluated the distribution of articles by journals. In light of this, journals can be divided into three zones, with each zone containing one-third of all publications (Tepe et al., 2022; Bhayani, 2024). The primary zones, Zones 1 and 2, have nearly the same number of articles (i.e., one-third), according to Singh et al. (2016). Nonetheless, the number of journals increases as we proceed from the core zone to Zone 1, suggesting that a select few are regarded as "core zone journals" and serve as the catalysts for any particular region. According to this law, the initial one-third of the publications are published by a small number of sources, which are the "core sources" influencing the subject. For the next one third of the articles, Zone I has more sources than Zone III, which displays the final one third of the articles and has the most sources. According to Bradford's law, the study's primary sources of publications on electric vehicles, environmental health, and sustainability research include "Sustainability (Switzerland)", "Journal of Cleaner Production", "Transportation Research Part A" and "Applied Energy" as shown in Figure 6. Additionally, 636 articles were published in 144 journals, according to the data in Table 5. The first group of four major journals, which are regarded as core journals on the subject, produced 227 papers; the second group of 15 journals, which are located in Zone 1, published 199 articles; and the following group, which consists of 125 journals, published 210 articles. According to these results, about one-third of research papers belong to each group, and as one moves from one zone to the next, the number of journals rises. According to Tepe et al. (2022), the findings in this part substantiate the assertion that research on EVs, EH, and sustainability is in line with the concepts of Bradford's law.

Table 5: Overview of Journal Literature

Category	Number of Journals	Journal Ratio	Loading Volume	Paper Ratio	Average loading density
Core Area	4	2.77%	227	35.69%	56.75
Relevant Area (Zone 1)	15	10.42%	199	31.29%	13.27
Discrete Area (Zone 2)	125	86.81%	210	33.02%	1.68

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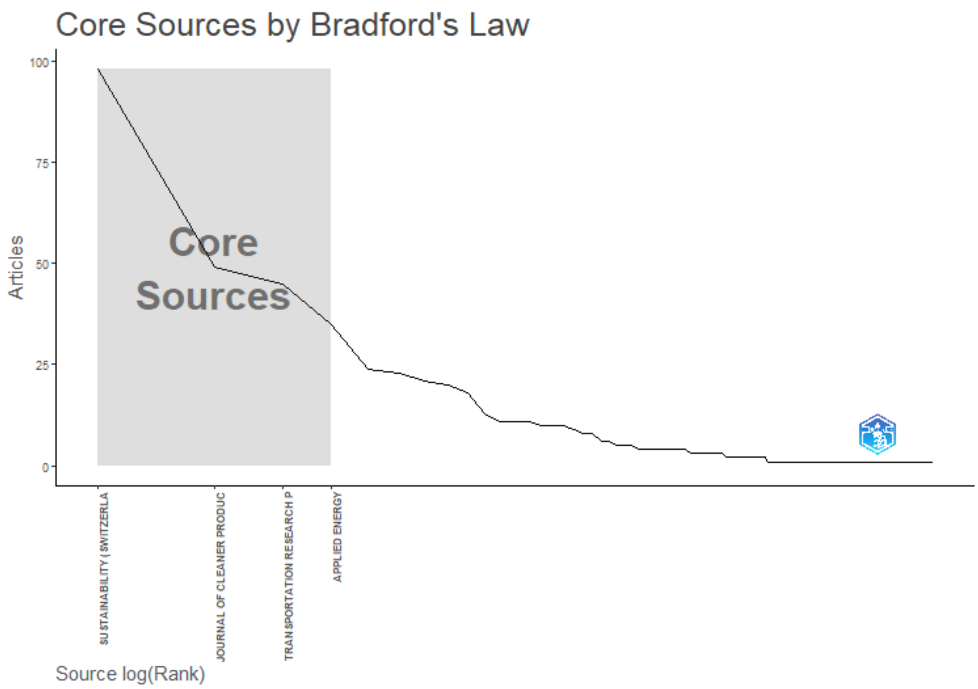

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Figure 6. Observed distribution vs. Bradford's law distribution

3.7 Affiliation analysis

Affiliation analysis in the figure 7 indicates the top 10 most contributing institutions in terms of number of articles in the field of EVs, EH and Sustainability research. Tsinghua University ranks the first position with 29 publications, followed by North China Electric Power University, University of Waterloo and University of The Basque Country (Upv/Ehu) with 23, 20 and 18 publications respectively.

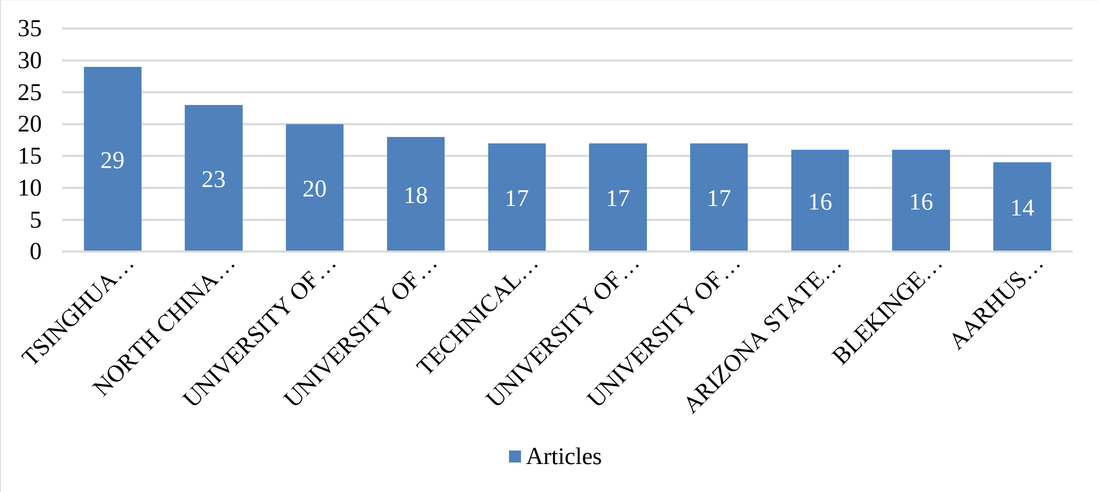

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Figure 7. Top 10 most prominent affiliations

3.8 Country Analysis

The global research influence in a particular topic is presented by the table 6, which gives an overview of the publication frequency and total citation count for research contributions by region. With 346 and 345 publications, respectively, the USA and China lead the world in publication volume. However, their study got 6,241 citations, compared to 4,583 for China, indicating a higher average effect per publication in the USA. The UK comes in second with 149 publications but a higher citation count of 2,731, showing significant influence in relation to output, while Germany comes in first with 198 articles and 1,856 citations. Other nations, such as Italy, Spain, and India, exhibit varying citation counts and moderate output, indicating regional variations in the impact of their publications. As presented in table 6 and Figure 8, Canada and Sweden have great research influence, although having lesser output, show significant citation impact (1,209 and 993, respectively) in relation to their output. Despite having 60 publications, Australia has a very low citation count of 402, which could indicate either more recent research with increasing citations or a field with a greater regional influence.

Table 6: Top 10 most productive countries based on articles and citations

Region	Frequency	Citations
USA	346	6241
CHINA	345	4583
GERMANY	198	1856
UK	149	2731
ITALY	117	1128
SPAIN	99	1248
INDIA	93	1465
CANADA	79	1209
SWEDEN	73	993
AUSTRALIA	60	402

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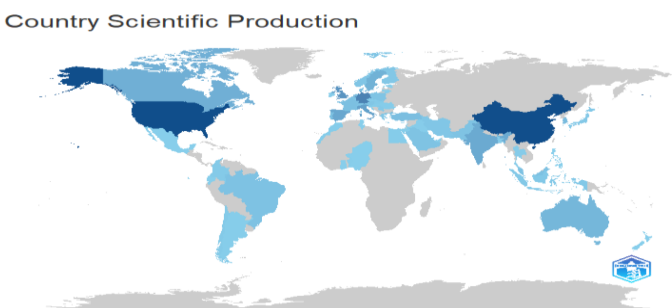

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Figure 8. Most prominent countries

3.9 Most Global Cited Documents

The total citations and average citations per year (TC per Year) of each work are displayed as indicators of scholarly influence in the table 7, which provides an overview of the citation impact of significant papers within a particular field of study. A substantial long-term impact is suggested by the study by Egbue (2012) in Energy Policy, which has the most citations overall (1,227) and an annual average citation of 94.38. With 706 citations and a high yearly rate of 88.25, Ahmad's 2017 paper in IEEE Transactions on Transportation Electrification comes next, demonstrating quick recognition. Both immediate and long-term research relevance are demonstrated by the moderate total citations (range from 276 to 351) and variable annual rates of papers by Richa (2014) in Resources, Conservation and Recycling, Guo (2015) in Applied Energy, and others. The recent and significant influence of sustainability-focused research is demonstrated by the papers in Nature Sustainability by Banza Lubaba Nkulu (2018) and Baars (2021), which have significant yearly citation averages (45.43 and 76, respectively). High citation counts indicate both foundational and trending research subjects, demonstrating the breadth of effect these works have in their respective fields (Garfield, 1972).

Table 7: Top 10 most productive papers

Paper	DOI	Total Citations	TC per Year
Egbue O, 2012, Energy Policy	10.1016/j.enpol.2012.06.009	1227	94.3846154
Ahmad A, 2017, Ieee Trans Transp Electrif	10.1109/TTE.2017.2771619	706	88.25
Guo S, 2015, Appl Energy	10.1016/j.apenergy.2015.08.082	351	35.1
Richa K, 2014, Resour Conserv Recycl	10.1016/j.resconrec.2013.11.008	343	31.1818182
Banza Lubaba Nkulu C, 2018, Nature Sustain	10.1038/s41893-018-0139-4	318	45.4285714
Baars J, 2021, Nature Sustain	10.1038/s41893-020-00607-0	304	76
Noppers Eh, 2014, Global Environ Change	10.1016/j.gloenvcha.2014.01.012	302	27.4545455
Biresselioglu Me, 2018, Transp Res Part A Policy Pract	10.1016/j.tra.2018.01.017	288	41.1428571
Jiang J, 2014, Energy Environ Sci	10.1039/c4ee00602j	287	26.0909091
Canals Casals L, 2016, J Clean Prod	10.1016/j.jclepro.2016.03.120	276	30.6666667

Source: Created by Authors

3.10 Tree Map Analysis

The relative emphasis on different study topics is shown in the Figure 9, tree-map representation, where the size of each block indicates how common the issue is in the field. The two most popular subjects are "sustainability" (11%) and "electric vehicles" (17%), indicating a high focus on these areas in line with worldwide trends toward the adoption of sustainable and low-carbon technology (IEA, 2021). The remaining noteworthy categories, "sustainable development," "decision making," and "environmental impact," each accounting for roughly 5% to 6% of the total, suggest secondary but important areas of attention in tackling resource management and climate change(Ekins et al., 2022). Smaller blocks address specific topics like "energy efficiency," "carbon emissions," and "renewable energy," demonstrating a varied and interdisciplinary approach to solving environmental issues (Summary, 2023). The wide emphasis on efficient and sustainable energy solutions as central subjects in current research is highlighted by this distribution.

Source: Created by Authors

Figure 9. Tree-map analysis

3.11 Thematic Evolution

R Biblioshiny was used in conjunction to VOSviewer to look at frequently used terms at various stages of the study's development while examining the relationship between EVs, EH, and sustainability. Figure 10 illustrates the topic evolution, which was created using Biblioshiny's "author keywords" and offers insights into the changing conceptual framework of research from 2010 to 2024. This study examines the connections and changes across topics throughout three distinct time periods—2010–2015, 2016–2020, and 2021–2024—to demonstrate the dynamic evolution of research themes in this area.

2010–15: At this early stage, there are three main study themes. Early conversations around energy use and the emergence of electric vehicles (EVs) were the main emphasis of these themes. 2016-2020: In this period, electric vehicles remain a prominent theme with a number of subthemes. 2021–2024: During this current period, there are just two EV-related study themes: sustainability and environmental health. Adoption of emission-reducing methods and technologies is also being given priority, which shows how important policy-driven approaches are becoming to the EV sector and sustainable transportation.

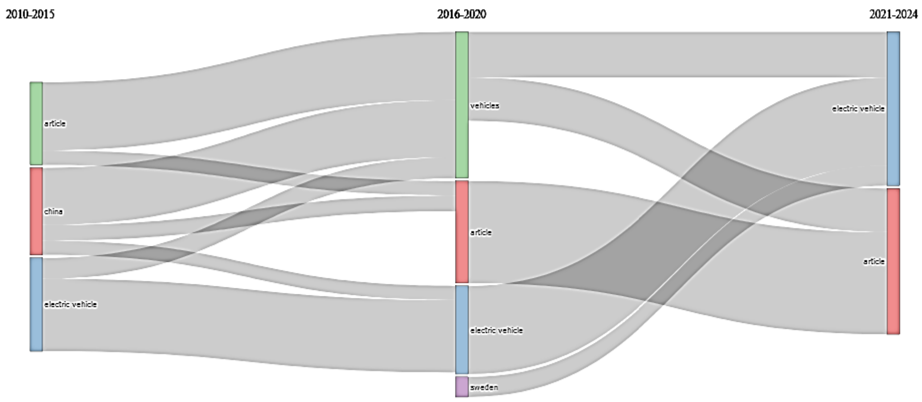

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Figure 10. Thematic evolution

3.12 Keyword Analysis

The term co-occurrence network is a crucial scientific method for identifying connections across various research fields and supporting the identification of novel research trends (Ülker et al., 2022; Saha et al., 2020; Wang, 2018). Figure 11 shows a graphical representation of the network that illustrates the frequency of keyword co-occurrence. According to the requirement that author keywords appear at least seven times, 41 out of 2093 author keywords satisfied the criterion. Based on VOS viewer analysis, the final network, shown in Figure 11, consists of 41 nodes grouped into seven distinct clusters. The fundamental study themes that these seven clusters represent are – (a) "Sustainable transportation and Policy", (b) "Sustainable mobility and Energy", (c) "Environmental Impact and Circular Economy", (d) "Electric Vehicles Adoption and Climate Change", (e) "Battery and Lithium-Ion Technology", (f) "Shared and Connected Mobility" and (g) "Smart Grid and Vehicle-to-Grid Integration".

3.12.1 Cluster 1: "Sustainable transportation and Policy" (Blue Cluster). It seems that general issues pertaining to electric vehicles and environmentally friendly transportation are at the centre of this cluster. It contains terms like "sustainable transportation," "electric vehicles," and "sustainability transitions." It stands for the wide range of research on how to incorporate electric cars into environmentally friendly transportation networks.

3.12.2 Cluster 2: "Sustainable mobility and Energy" (Red Cluster). These themes include "renewable energy," "sustainable mobility," and "urban mobility." The red cluster most likely represents research on urban planning, sustainable mobility policies, and the integration of electric vehicles with renewable energy sources.

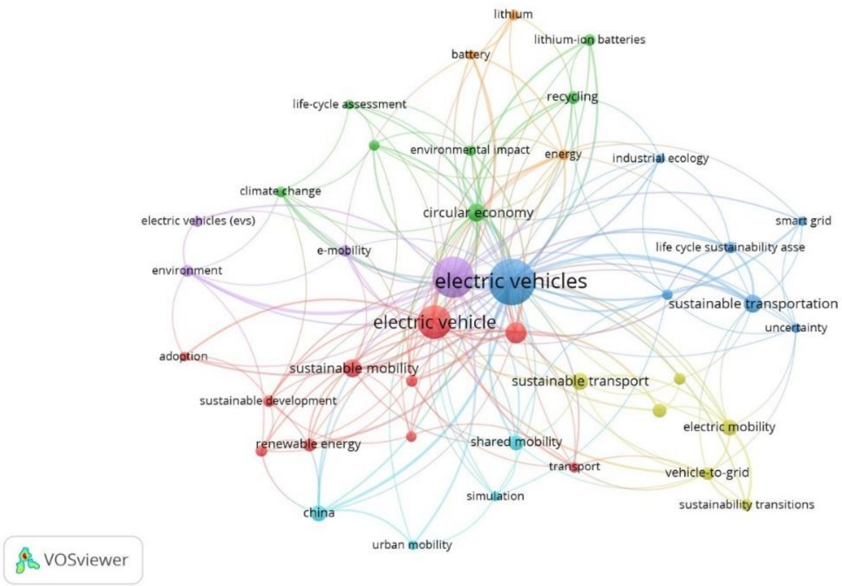

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Figure 11. Keyword co-occurrence network

3.12.3 Cluster 3: "Environmental Impact and Circular Economy" (Green Cluster). This cluster contains keywords such as "industrial ecology," "circular economy," "environmental impact," and "recycling." The environmental effects of electric vehicles, such as life cycle assessment, battery recycling, and the contribution of a circular economy to the sustainable lifecycle of electric vehicle components, are the main topics of this cluster.

3.12.4 Cluster 4: "Electric Vehicles Adoption and Climate Change" (Purple Cluster). Some of the terms in this cluster are "electric vehicles (EVs)," "environment," "climate change," and "adoption." It might be studies looking into how EVs are being adopted by the general population, how they help cut carbon emissions, and how climate change policies affect the rise in EV use.

3.12.5 Cluster 5: "Battery and Lithium-Ion Technology" (Yellow Cluster). These keywords are the focus of this cluster: "lithium," "lithium-ion batteries," and "battery." Technical study into battery technology, particularly lithium-ion batteries, which are essential parts of electric cars, is probably what it represents.

3.12.6 Cluster 6: "Shared and Connected Mobility" (Cyan Cluster). Terms like "shared mobility," "simulation," and "transport" are included in this cluster. In addition to the use of simulations in transportation studies, it represents research on shared mobility systems (like car-sharing) and how electric vehicles can be incorporated into these models.

3.12.7 Cluster 7: "Smart Grid and Vehicle-to-Grid Integration" (Orange Cluster). This cluster's keywords include "vehicle-to-grid," "smart grid," and "sustainability transitions." The technological components of connecting electric vehicles to the power grid are represented by this cluster. These include smart grids and vehicle-to-grid (V2G) technologies, which enable EVs to store and return electricity to the grid.

From technological and environmental viewpoints to policy and mobility integration, each of these clusters focuses on a distinct facet of electric vehicle research. When combined, they offer a thorough understanding of the multidisciplinary character of research on electric vehicles.

4. Discussion and Conclusion

This study highlights the evolution of the EV, EH and Sustainability domain from 2010 and 2024 by analyzing 636 publications indexed in Scopus using VOSviewer and the R bibliometric tool. In response to RQ1, the study shows the publication pattern which demonstrates a consistent rise in publishing articles on the topic. Following this high, there is a minor decline in the number of articles, with 92 in 2022 and 74 in 2023 before a sharp decline to 15 in 2024. This trend points to a gradual increase in interest in the subject over time, followed by a minor drop in recent years, which could be the result of publishing rate saturation or other outside influences.

In response to RQ2, in respect of most prominent source, Sustainability (Switzerland) journal dominates the sector with 98 articles and 2,763 citations. In respect to most contributing author, SOVACOOL BK is the prominent in their field, with 13 articles and 982 citations, demonstrating both great output and influence. Country analysis shows that, the USA and China lead the world in publication volume, with 346 and 345 publications, respectively. Tsinghua University ranks the first position with 29 publications, followed by North China Electric Power University, University of Waterloo and University of The Basque Country (Upv/Ehu) with 23, 20 and 18 publications respectively.

In response to RQ3, the fundamental study themes and seven clusters represent in the study are – (a) “Sustainable transportation and Policy”, (b) “Sustainable mobility and Energy”, (c) "Environmental Impact and Circular Economy", (d) "Electric Vehicles Adoption and Climate Change", (e) "Battery and Lithium-Ion Technology", (f) "Shared and Connected Mobility" and (g) "Smart Grid and Vehicle-to-Grid Integration".

In response to RQ4, the most productive publication is the study of Egbue (2012) in Energy Policy, which has the maximum citations, i.e., 1,227 and an annual average citation of 94.38.

In order to address RQ5, the study employed bibliometric laws and contrasted the results with those of Bradford's and Lotka's laws. The findings contradicted Lotka's law but validated Bradford's law. In response to RQ6, the following future research directions are indicated by the seven thematic clusters.

Future Research Directions

Table 8. Future research directions

Cluster	Theme	Future Research Prospects
1.	Sustainable transportation and Policy	With a focus on emission reduction and sustainable urban planning, future research should concentrate on integrating electric vehicles (EVs) into sustainable urban transport infrastructure. Research might evaluate how different policies, such as subsidies or low-emission zones, affect the rates of EV adoption and investigate efficient multi-modal transportation choices that combine EVs with public transportation and other environmentally friendly modes of transportation.
2.	Sustainable mobility and Energy	In order to reduce dependency on fossil fuels, research in this field should focus on optimizing EV charging systems to employ renewable energy sources like solar and wind. As EV adoption increases, research on energy supply and demand balance will be crucial, with a particular emphasis on renewable energy sources' ability to manage the fluctuating demand patterns of EV charging. Research can also look into sustainable urban mobility models that use electric vehicles (EVs) in conjunction with renewable energy sources to create low-carbon urban transportation options that lessen pollution and traffic.

3.	Environmental Impact and Circular Economy	Future studies should examine effective EV battery recycling procedures as well as second-life applications that recycle used batteries for different purposes like residential energy storage. To guide sustainable practices throughout the sector, improved life cycle assessment (LCA) models are required to assess the environmental implications of EVs from manufacture through disposal. In order to lessen the supply concerns and environmental impact of battery manufacturing, research might also concentrate on developing alternatives to essential components like cobalt and lithium.
4.	Electric Vehicles Adoption and Climate Change	Consumer perceptions of EVs should be examined in this research, taking into account issues like cost, charging infrastructure, and range anxiety. In order to determine which climate policies best meet consumer expectations and climate goals, studies could also assess how effective policies are at increasing the uptake of electric vehicles. Designing policies that optimize EVs' potential to reduce greenhouse gas emissions and hasten their adoption is crucial to mitigating the effects of climate change.
5.	Battery and Lithium-Ion Technology	The future of EVs depends on advancements in battery technology; research is required on next-generation batteries, such as solid-state batteries, which provide higher energy density, quicker charging, and lower costs. It will also be essential to increase battery lifespan and enhance battery management systems (BMS) to stop deterioration. Additionally, to guarantee long-term durability and public confidence in EV technology, attention must be paid to enhancing battery safety, especially in high-energy conditions.
6.	Shared and Connected Mobility	In order to determine how autonomous EVs could revolutionize urban transportation by eliminating the need for private vehicle ownership and providing new mobility options, research should examine the possibilities of shared and autonomous electric mobility systems. Research on ride-sharing and car-sharing schemes can assess the potential effects of shared EVs on parking needs, traffic jams, and urban pollution. In order to maximize vehicle deployment and comprehend the impact of extensive shared mobility on transportation networks, simulation and modeling will also be helpful.
7.	Smart Grid and Vehicle-to-Grid Integration	Future studies should concentrate on how EVs can be integrated with V2G technologies and smart grids to support grid stability by serving as distributed energy storage devices. Research on smart charging infrastructure might look at how dynamic charging systems can give priority to charging when renewable energy is abundant or during off-peak hours. For V2G to be widely adopted and potentially benefit both consumers and energy providers, research on the technological and regulatory issues surrounding it, such as creating standards and business models, is also crucial.

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Reference

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