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Charging Ahead: Key Drivers and Barriers to Electric Vehicle Adoption in Africa – A Bibliometric Analysis

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Abstract

Electric vehicles (EVs) are increasingly being acknowledged worldwide for their environmental sustainability, energy efficiency, and positive impact on health. However, their adoption in Africa remains underexplored, with significant gaps in understanding the factors driving and hindering their uptake. This bibliometric analysis reviews 1,058 articles published from 2004 to 2023 in the Web of Science database, focusing on EV adoption trends in Africa. The findings show a significant increase in publications post-2014 with over 300 articles published annually, though Africa's research output lags behind global averages. Moreover, several gaps remain, particularly in geographic coverage, longitudinal analyses, consumer behavior, comparative studies, and the integration of renewable energy. Key research themes identified include charging infrastructure, policy frameworks and consumer behavior. The study underscores the essential for inclusive policies which support infrastructure progress and consumer incentives to overcome barriers such as range anxiety and high costs. In addition to the most frequently researched topics, the study examined distinguished writers, journals, and nations related to EVs adoption in Africa. Depending on only the Web of Science database may be missing some pertinent publications, which is taken as limitation of this study. By including other data bases in the future, comparative studies between African countries and other developing regions could provide valuable lessons and best practices and also explore socio-economic and cultural factors influencing EV adoption.

Keywords: *Adoption, Africa, Bibliometric analysis, Electric Vehicles, Web of Science*

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1. Introduction

Greenhouse gases (GHGs) emissions into the environment is a cause for world climate change hence the issue has got a due attention by the international community (Fan et al., 2023). It is UK's energy white paper 'Our Energy Future: Creating a Low Carbon Economy' that familiarized the thought of 'low carbon' in 2003, and research on this concept began concurrently (Wang et al., 2022; IEA, 2022). From this carbon emission, transportation is the second largest and accounts from 23% to 37% (Patel et al., 2021; IEA, 2022; Ullah et al., 2023;). Cognizing this, carbon emission reduction is a great concern of today as well as the future to address the issue as immediately as possible (Egbue & Long, 2015; Fan et al., 2023;). EVs offer a promising alternative to fuel vehicles, significantly contributing to air pollution and urban congestion. Also, the continent has abundant renewable energy sources, such as wind and solar, which can be linked to charge EVs. This potential makes Africa ideal for integrating renewable energy with EV infrastructure (Bonah et al., 2023; IEA, 2024).

It is time to take serious actions on causes of environment degradation (Dong et al., 2021), though it is late, and EVs are from the main means to alleviate the problem (Shunmathy & Selvam, 2025; Kim & Park, 2025). If the outcomes of recent climate change conferences, such as COP24, can't make substantial progress towards the 'Paris Agreement Goals', it is probable that GHG releases will continue to accumulate rapidly in the future, increasing the chance of severe climate-related consequences with potentially catastrophic social and economic costs (Morgan, 2020). EVs are energy efficient (Yao et al., 2023), solutions for health problem created by conventional vehicles (CVs) gas emission (Dong et al., 2021), address sound pollutions (noise) of ICEVs (Ullah et al., 2023), minimizing of (Asha'ari et al., 2024) and tackling the concern of fuel energy sources depletion (Gabriel et al., 2021). Adopting EVs at a large scale enables to mitigate environment pollution that leads to health problem and global warming in addition to benefiting from energy efficiency and affordability (Goel et al., 2021; Ullah et al., 2023; Asha'ari et al., 2024).

Publication increases in a field has a big contribution to develop the field. The influence of global climate initiatives and policies on growth trends of publications about EVs is paramount (Dilotsotlhe, 2022; Fan et al., 2023). The Kyoto Protocol, which is another turning point for sustainable environment, is an agreement among 179 countries to achieve emission limitation and reduction binders under Article 3 to promote sustainable development that has to be implemented in accordance with the countries' policies and measures as well as national circumstances (United Nations, 1998). The first-ever universal, which sought to take meaningful global action against climate change, legally binding global climate agreement at the 'Paris Climate Conference among' 195 states was adopted by the nations in 2015 (Dilotsotlhe, 2022; Fan et al., 2023). Further, transitioning to EVs can stimulate economic growth by reducing imported fossil fuels dependency and fostering local industries related to EV manufacturing and infrastructure development (Dong et al., 2021). Several African countries are beginning implementing incentive policies to promote EV adoption. Understanding the effectiveness of these measures and identifying best practices can enlighten future policy development across the continent (Ottesen et al., 2022).

EVs on road have been increasing since the beginning of the 21st century (Martins et al., 2023). There are more and more reasons to switch to EVs these days. These include the extremely high fuel economy of EVs, growing and unstable gas costs, GHG emissions, and increased dependence on imported petroleum

(Egbue & Long, 2015). There were about 14 million new EVs registered worldwide in 2023, increasing the total number of EVs on the road to 40 million. Of which China, Europe, and USA accounted for 95%. As IEA (2024) boldly stated there was a 35% annual rise of sales of EVs in2023 which is an increment by 3.5 million compared to 2022. Compared with 2018, which was five years ago, it is more than six fold higher. The big change in EVs number is due to the adoption of prevalent EV technologies by several countries, especially technologically advanced countries (Candra, 2022; Fan et al., 2023). In 2023, battery-powered EVs account 70% of the total EV inventory (IEA, 2024). Despite the potential benefits, Africa is often underrepresented in global EV research. By focusing Africa, this study seeks to contribute valuable insights into how the continent can overcome barriers and leverage its unique advantages to accelerate the adoption of EVs. The study summarizes the available researches both systematically and scientifically in the EV adoption domain by finding out the trends of future research. Thus, the authors specifically conducted an in-depth analysis of the primary barriers as well as drivers associated with familiarizing EVs including recommendations for various stakeholders: scientists, manufacturers, and governments' officials. Additionally, to assess the leading research contributors in the field of EV adoption, including authors, sources, and countries, over a specified period. Finally, to identify trends in the distribution of articles related to EV research from 2004 to 2023.

This research analyzed the development of literature in Africa on EV adoption during the period of 2004-2023. Although there has been a flow of researches on the adoption of EVs and renewable energy sources in recent years, significant gaps in knowledge still exist in the published literature (Amedokpo & Boutueil, 2022; Bonah et al., 2023). In Africa, EV research is comparatively new. Between the two oil shocks (1973 and 1979), which served as genuine catalysts for EV research, the earliest indication of publishing in the scientific journal is from 1978 (Amedokpo & Boutueil, 2022).

Bibliometric studies organize and summarize existing literature to examine and categorize the content. This approach has been employed in previous studies to evaluate journals (Barbosa et al., 2022; Olaleye et al., 2023; Moyo et al., 2024; Shunmathy & Selvam, 2025). The global shift toward EVs as a sustainable transportation solution is gaining traction, yet the adoption of EVs in Africa remains limited.

EVs adoption is a growing area of research, particularly given the global push towards sustainable and environmentally friendly transportation solutions. IEA (2024) emphasized that nations' policies are important parts for the wide acceptance of EVs. Africa, with its unique socio-economic and infrastructural challenges, presents a distinctive case for studying EV adoption. A few studies have been done on EV adoption in Russia and Brazil (Habich-sobiegalla et al., 2018) and this worsens in Africa. Only 4 of the 346 publications examined in a systematic literature review by (Desai & Patel, 2023) are from Egypt, Morocco, Nigeria, or South Africa. In another reviewed study titled "Consumer Adoption of Electric Vehicles: A Systematic Literature Review" by Bryła et al. (2023) that examined 57 peer-reviewed researches published during 2015-2022, not a single document from an African country was included. Moreover, Bonah et al. (2023) reveals that very little is known about fuel vehicle transportation alternatives in Africa, including the industry's challenges and opportunities.

The main gaps recognized in the literature are inadequate geographic coverage, lack of longitudinal studies, limited research on consumer behavior and social acceptance of EVs in Africa, and few studies comparative studies This study identifies several gaps in existing research. Thus, the study has the following objectives:

1. To explore most commonly studied drivers of EV adoption in Africa

2. To assess which barriers of EV adoption in Africa are most frequently cited?

3. To evaluate the economic and environmental impacts of EV adoption in the continent

4. To assess which countries and regions in Africa are most represented in the literature

5. To identify leading authors, institutions, and journals on EV adoption in Africa

In this research paper, we examined crucial components and current trends in EV adoption field, and offer insights for scholars working in this area. The research questions are:

1. What are the most commonly studied drivers of EV adoption in Africa?

2. What barriers of EV adoption are most frequently cited in the literature in Africa?

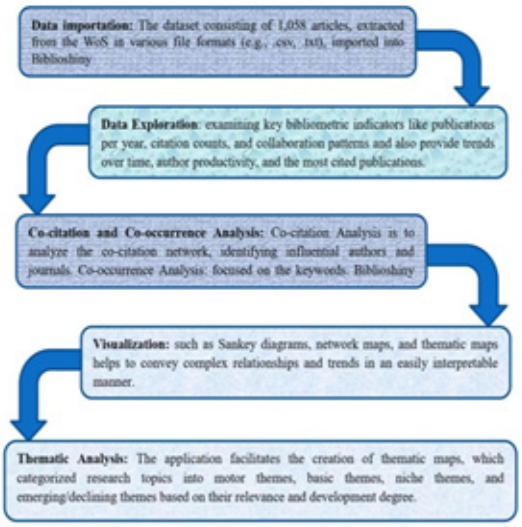
3. What economic and environmental impacts do EVs have in the region?

4. Which countries and regions within Africa are most represented in the literature

5. Who are the leading authors, institutions, and journals contributing to the research on EV adoption in Africa?

2. Methodology and Data Sources

This literature review uses Bibliometric to analyze the scientific production on the topic of EVs adoption. Bibliometric analysis is a statistical method used to analyze publication trends quantitatively (Singh et al., 2023). Authors utilize tools like Bibliometrix and VOSviewer to perform co-authorship analysis, citation analysis, co-citation analysis, and co-occurrence analysis. These approaches identify key contributors, trends, and research networks, whereas thematic analysis sets related papers into key themes by clustering techniques (Shunmathy & Selvam, 2025; Kim & Park, 2025). Figure 1 and 2 depict the methodology and data sources clearly.



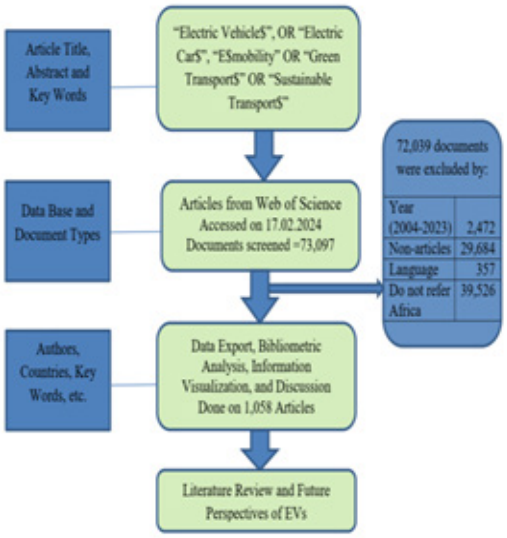


Figure 1(left): Steps in using Biblioshiny Figure 2 (right): Document Screening Method

Bibliometric analysis as a process starts with data collection, then data loading, data analysis, discussion, and conclusions with showing future research directions (Adewale et al., 2023; Yao et al., 2023; Shunmathy & Selvam, 2025). It is an efficient tool for analyzing and visualizing the vast amounts of scientific knowledge that are constantly evolving in a particular field, as it can effectively handle unstructured data (Moyo et al., 2024; Kim & Park, 2025) The authors of this article searched articles in the Web of Science which covers most of the primary journal publications in the world (Asha'ari et al., 2024), though it may ignore regional publications and journals not indexed in its database possibly leading to a partial picture of EV research in Africa, using a combination of keywords: though some authors define "electric vehicles" as a broad category that includes all types of EVs, such as automobiles, buses, lorries, and motorbikes (Desai & Patel, 2023).

Within the electric vehicle domain, "Electric Vehicle$", OR "Electric Car$", "E$mobility" OR "Green Transport$" OR "Sustainable Transport$" AND "Adoption" OR "Intention" OR "Accept$" OR "Repurchase Intention" were the search words and the geographical context was Africa to make the search comprehensive. All included documents are written in English language and all are articles. The articles were published between 2004 and 2023 believing that the number of articles published before 2004 is insignificant. From scholarly papers in Web of Science, 1058 articles were extracted in the mentioned timespan. In order to refine the search to journal articles, document type, language, and publication stage, we eliminate unpublished articles, conference papers, and other language interference types. The authors used Bibliometric indicators such as total number of publications, annual average, and citations to analyze the scientific production. The analysis provides an overview of the scientific production on the topic and identifies key themes and trends in the literature in the field of EVs in Africa.

In order to get quality data, data cleaning, data integration, and software familiarity were done ahead and during data processing. Bibliographic data from the Web of Science frequently contained inconsistencies, such as variations in author names and journal titles, and required data cleaning and removing of duplicates to ensure accuracy in analysis. Ongoing validation checks throughout the data processing

stages were implemented to minimize errors and ensure data accuracy. Authors required learning of Biblioshiny's capabilities to fully understand and utilize it accordingly.

3. Results of Bibliometric Analysis

From research techniques used to systematize research, Bibliometric analysis enhances to find scientific trends, and guarantee the accuracy of the data and output of the findings (Barbosa et al., 2022; Yao et al., 2023; Kim & Park, 2025). The Web of Science data platform, which is regarded as an excellent database for Bibliometric analysis once that covers information published in indexed journals in numerous fields of knowledge (Fan et al., 2023; Yao et al., 2023; Shunmathy & Selvam, 2025), is where the documents used in this study were gathered. Bibliometric analyses have made extensive use of this resource (Fan et al., 2023; Kim & Park, 2025). On 13 February, 2024, 1058 journal articles were found through the search after screening, which was conducted using keywords "Electric Vehicle$", OR "Electric Car$", "E$mobility" OR "Green Transport$" OR "Sustainable Transport$" AND "Adoption" OR "Intention" OR "Accept$" OR "Repurchase Intention" during 2004 to 2023 in Africa.

4.1. Dataset Features

The number of documents published in 285 sources between 2004 and 2023 are 1,058. They are taken from the Web of Science database. Figure 3 shows that the average citation rate of the analyzed documents is 16.08, and the average number of citations per year for each document is 3.37. A total of 36,597 references have been cited in the publications included in the study. The authors' keywords total of 3,839 is more than twice the number of papers that the authors of the analyzed documents used as keywords. In the meantime, the keyword plus is 1,478. From the 3,292 authors, 33 were found to have written independently and 1,025 of them have collaborated. 28 articles of the reviewed documents had a single author. Each author has published 0.32 papers on average and the average authors per publication are 3.11. Furthermore, the Figure shows that there are 4.86 co-authors for each document. For the documents under analysis, the cooperation index, which measures the proportion of total authors to total authors of multi-author publications, is 3.20.

Figure 3: General description of the articles

4.2. Most Cited Countries and Affiliations

Based on the analysis of the documents, 62 countries have been recognized as having made scientific contributions to EVs. Egypt, with 190 articles, has the highest number of these contributions, which can be explained by the fact that Egypt is regarded as a country that has paid relatively adequate attention to research on the widespread adoption of EVs in Africa. Algeria, China, France, and the United States of America follow Egypt in order of importance, with 104, 87, 55, and 31 articles in the top five,

respectively. Because of factors like equipment availability, research funding, and access to a favorable atmosphere, researchers' affiliation or location greatly influences the quality of their work. In order to better facilitate academic exchanges and scientific research cooperation, it can identify the scientific research institutions that have published more in the field of study through quantitative and qualitative analysis of the number and duration of scientific research institutions.

On this regard, Aswan University is the first top with 128 articles followed by Alexandria, Cairo, Minia and Zagazig universities with 80, 68, 66, and 63 articles respectively. Moreover, figure 4 and 5 show top ten countries and affiliations respectively.

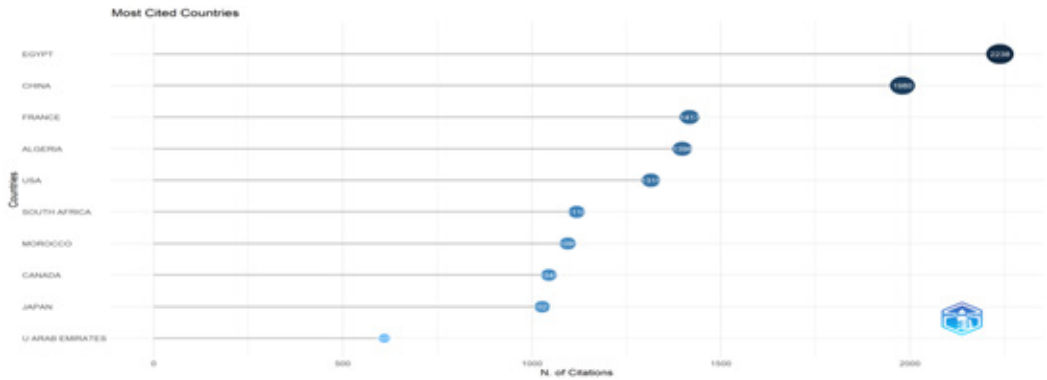


Figure 4: Top ten most cited countries

Most cited countries are presented in Figure 5. The figure shows the number of citations received by research publications from various countries. Each bubble represents a country, with its size and position indicating the total number of citations. Based on this, Egypt is the most cited country, with 2,237 citations. It has the largest bubble and is positioned farthest to the right, indicating its dominant position. China follows Egypt 1,980 citations. It has the second-largest bubble, reflecting a strong citation impact. Although Egypt leads in publications it lags in market uptake, while South Africa shows stronger adoption (IEA, 2024) despite scarcer studies.

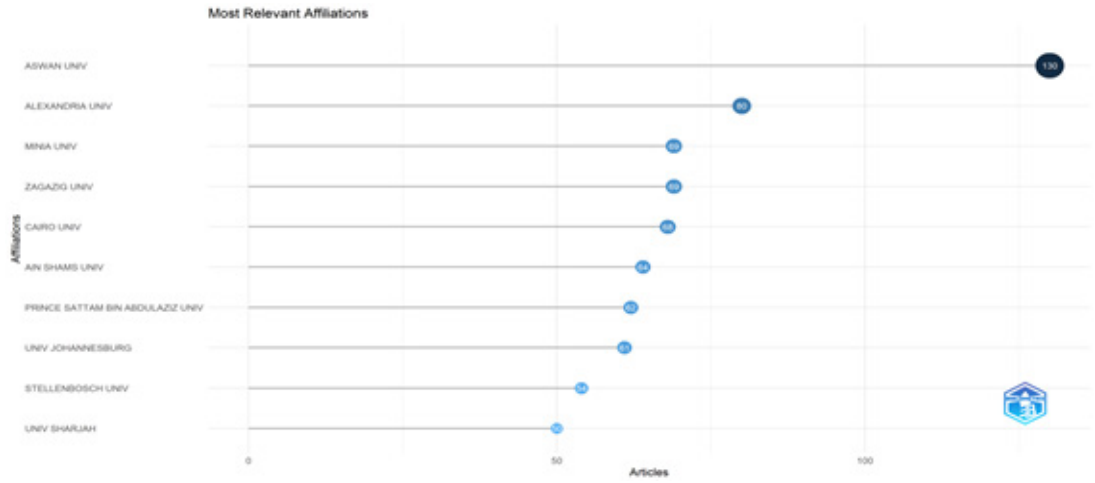


Figure 5: Top ten most relevant affiliations

4.3. Top Authors and Sources

Professional writers and sources critical analyses can offer priceless insights into the state of science and the implications of research on any given subject. The top 10 authors, shown in Figure 6, are chosen for analysis and ranked based on total number of publications in this discipline. In the timespan, most active researchers on the subject have published between 15 and 22 documents (17.6 on average).

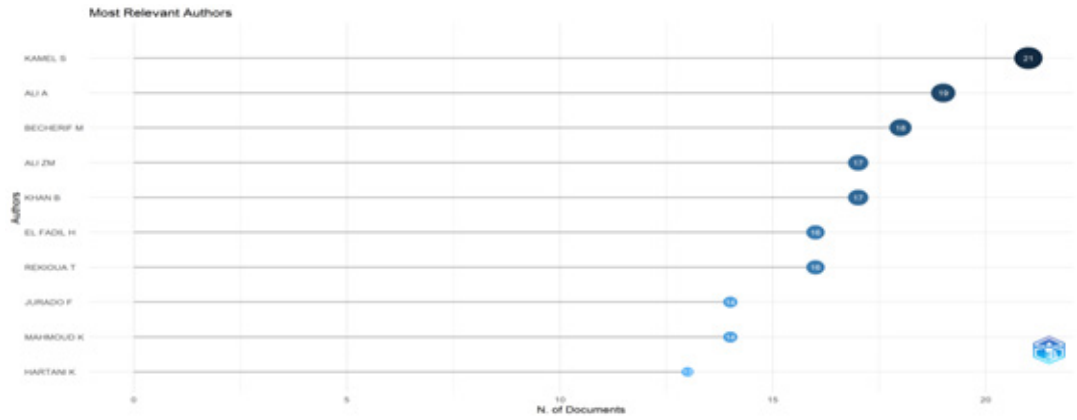


Figure 6: top ten relevant authors

As the Figure shows top 10 active researchers on EVs research in the time span reveals, Kamel S. has written 22 publications (2.08% of TP) on the subject area, more than any other author, followed by other influential authors Ali A. with 20, Becherif M. with 18, and Abdel K., El-Fedal H., Hasaneh H., Khan B., and Rekoua T. with 17 each. The fact that these leading scholars together account for 11.67% (176 articles) of all publications (TP) suggests that they are the most important people working on the subject.

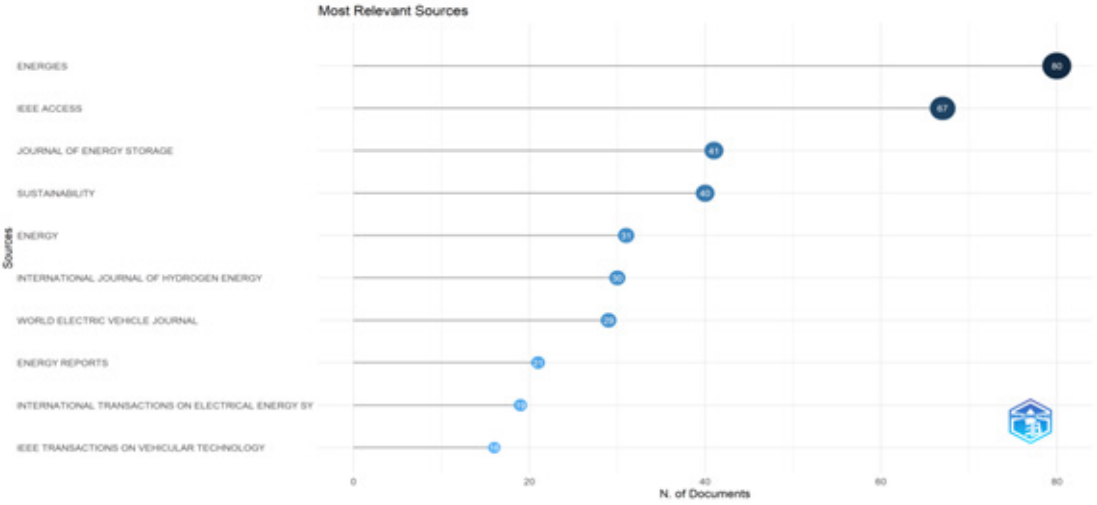


Figure 7: top ten relevant sources

With 80 documents (7.56%), the journal "Energies" has the most documents overall. With 67 documents (6.33%) and 40 documents (3.78%) respectively, journals "IEEE Accesses" and "Sustainability" are the second and third most document-rich journals on the subject. These figures allow the journal's focus on

EVs to be examined in greater detail. The publications cover multidisciplinary topics like sustainability, energy, and transportation. Figure 7 shows larger journal node indicates the greater quantity of journal papers.

4.4. Trend Analysis

An analysis of the annual number of scientific publications can provide a fast picture of a study topic's trend. Figure 8 illustrates that 1,058 papers were published in 20 years, averaging 53 per year, between 2004 and 2023. Research on EVs has gained popularity among academics in recent years. We may therefore infer the upward trend of scientific activity that increased the significance of research on EVs and energy efficiency.

4.4.1. Annual Scientific Production

Trend of a study topic can be ascertained by analyzing the annual quantity of scientific publications (Fan et al., 2023; Ubana & Ubana, 2023). Figure 8 tells that during 2004-2013, there were remarkably few publications in a ten-year period; 1 publication in 2004 and 1 in 2005. The analysis revealed that the annual number of publications to have seen a massive increase over the past decade, with 308 publications recorded during the year 2023 as compared to 17 publications during 2010, clearly indicating the growing interest in EVs among the researchers. Researchers have been paying close attention to battery, charging station, energy storage, optimization, and renewable energy in the field of EVs in recent years. Therefore, we may deduce the increasing trend of scientific activity that concentrated study on energy storage, charging infrastructure, and EV energy optimization.

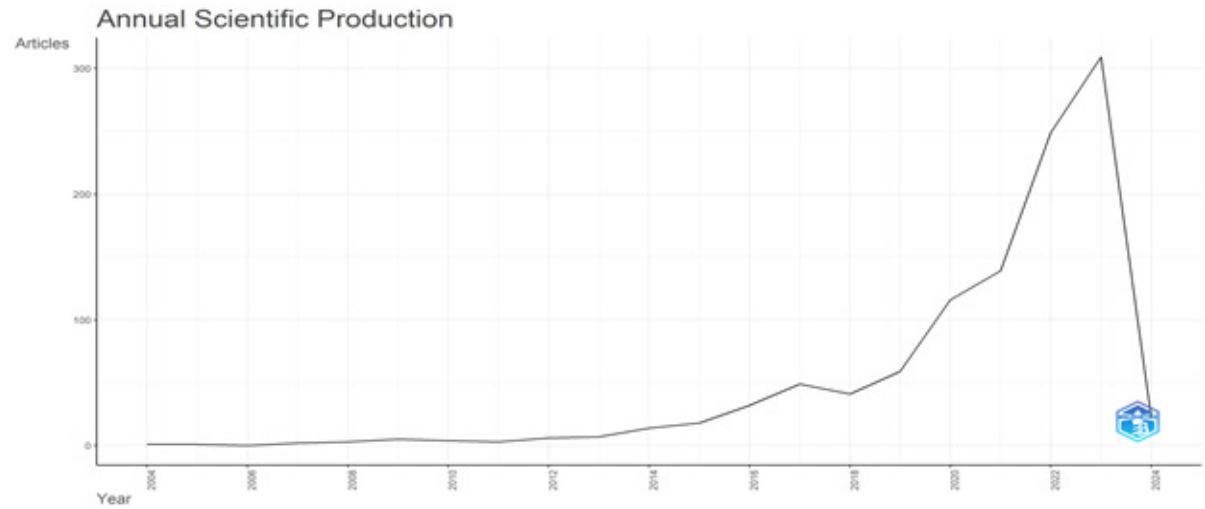


Figure 8: Annual scientific production

4.4.2. Authors' Production Overtime

Figure 9 below depicts the publication output of various authors including Kamel S., Alia A., Becherif M., Abdel-Khalik A.S., El Fadil H., Hasnain H.M., Khan B., Rekoua T., Ali Z.M., and Mahmoud K over time from 2014 to 2023. Each dot on the chart implies a year in which an author published articles, with dot size indicating the number of articles published that year. Larger dots correspond to a higher number of publications, with a legend showing dots representing 5 and 10 articles and TC per Year with markers

for 20, 40, 60, and 80 citations.

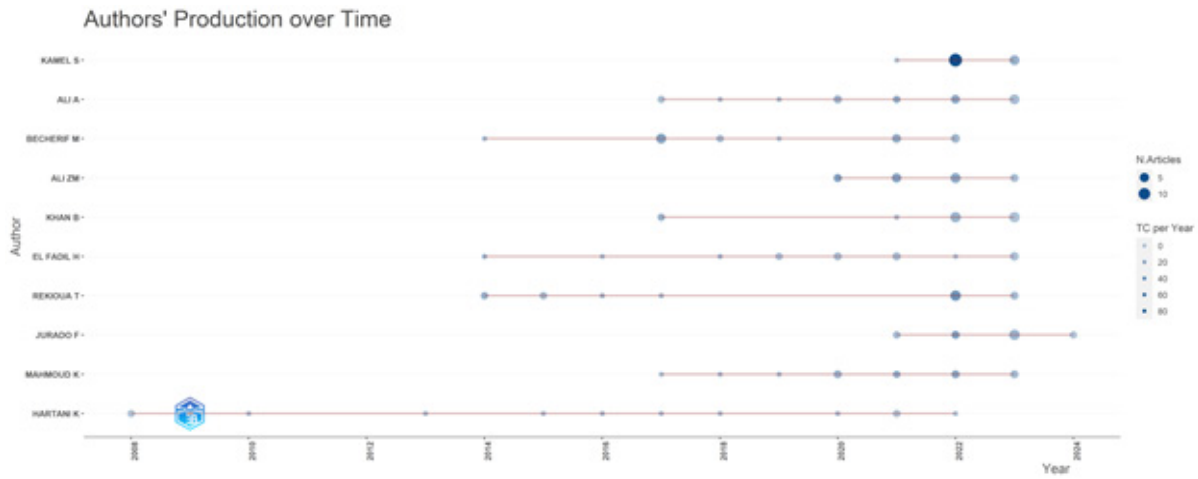


Figure 9: authors' production overtime

4.4.3. Trend Topics

As it is clearly shown in figure 10 the trend topics are spanning from 2009 to 2023. Each dot on the chart represents the frequency of a term in publications for a given year, with the size of the dot indicating the term frequency. As study progresses the frequently used words change. "Electronic differential" is the word that appeared the most frequently in 2011, according to Bibliometric. The terms "electric vehicle" and "electric vehicles" were used most frequently in the literature in 2022 and 2023, respectively. The dot with darker hue received more citations. The total number suggests that EV research is changing. Based on how frequently authors use certain keywords, trending themes are examined. The term "frequency" describes the number of a keyword appears in publications throughout that specific year (Fan et al., 2023). Between 2004 and 2009, as it can be seen in the Figure, there is no frequently observed keyword whereas since then, in addition to electronic differential, words like direct torque, induction motor, distribution system, and motor drives were frequent keywords till the end of 2014. PHEV, traction, electric differential were frequent words in addition to induction motor, distribution system, and motor drives in 2015 and fault-tolerant control and propulsion in 2016. Super capacitor, fuzzy logic and super capacitors emerged as frequent words in 2017. Fuzzy, smart grid and battery were widely used terms in EVs adoption documents in 2018 in addition to the extended ones from 2017.

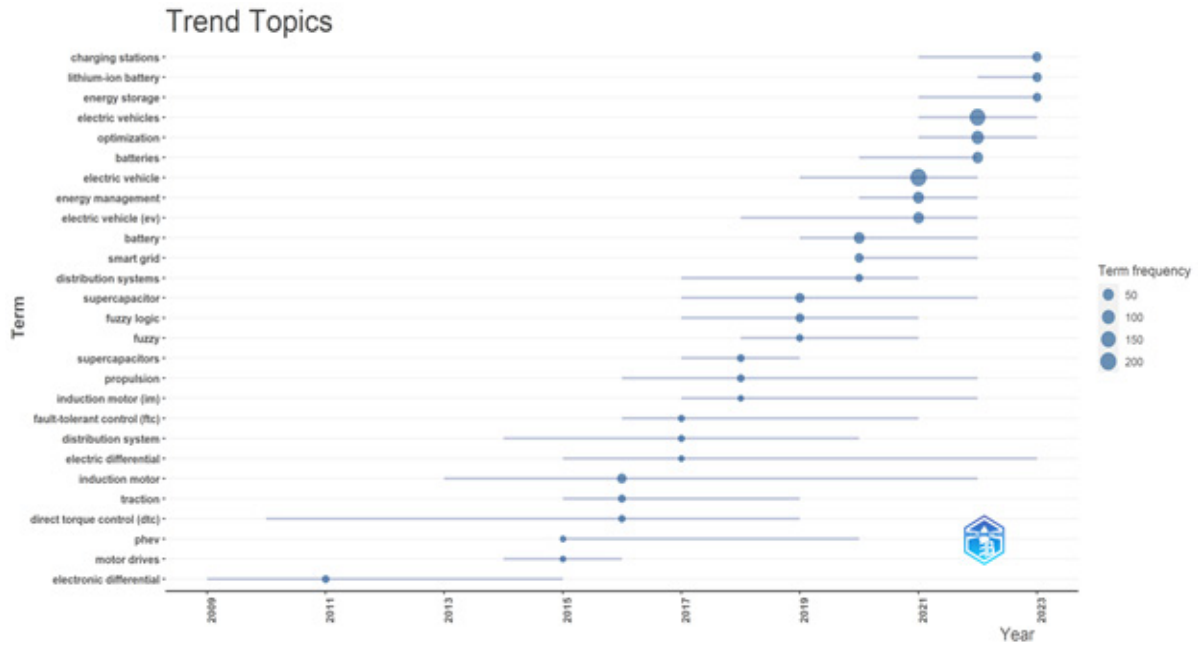


Figure 10: Trend Topics

Electric vehicle (the dominant word in this analysis) and energy management strategy were frequently used words in 2019. Batteries and energy management were emerged as frequent words in 2020. Charging stations, energy storage, electric vehicles and optimization were introduced frequent words electric vehicle being the highly repeated word in 2021. These words continued being frequently used ones in 2022 and 2023 electric vehicles being the dominant word. Recent trends (2018-2023) reveal that the terms "charging stations," "energy storage," "energy management strategy", and "electric vehicles" have seen a significant rise in frequency, especially, post-2018. The size and density of dots for these terms increase, indicating growing interest and research output in these areas. During 2005-2023 there are consistent trends; terms like "electric vehicle," "optimization," "batteries," and "energy management" show consistent usage over the years, with notable increases in recent years, reflecting their sustained relevance in research. Emerging topics within 2010-2023 such as "battery management system," "supercapacitors," "fuzzy logic," and "induction motor" show a marked increase in frequency from around 2010 onwards, with a significant rise around 2017-2018.

4.5. Countries' Scientific Production and Collaboration

Country scientific production and collaboration provides an overview of scientific output and collaboration related to EVs across different nations worldwide. In this research Egypt is leading in collaborating with 59 countries and 746 frequencies. The nations that are most interested in studying energy efficiency and impact of EVs on emissions are those that have greatest influence over exchange of visits and academic collaboration among researchers from different nations.

It should be noted, however, that the quantity and intensity of scientific production and collaboration do not necessarily indicate the quality of research conducted in different countries. Figure 11(right) depicts international cooperation between nations, whereas Figure 11(left) shows each nation's contribution to science. This section offers citation-based analysis of how scientific research affects EVs' energy

efficiency and ability to reduce emissions. The authors' ranking of the nations and the region is based on the total amount of citations that each nation has received. Egypt has the most citations (2237) on the list. With 1980 and 1714 citations, respectively, China and Algeria came in second and third place. From the top ten collaborating countries with others, Egypt, China, and Saudi Arabia are ranked 1, 2 and 3 respectively.

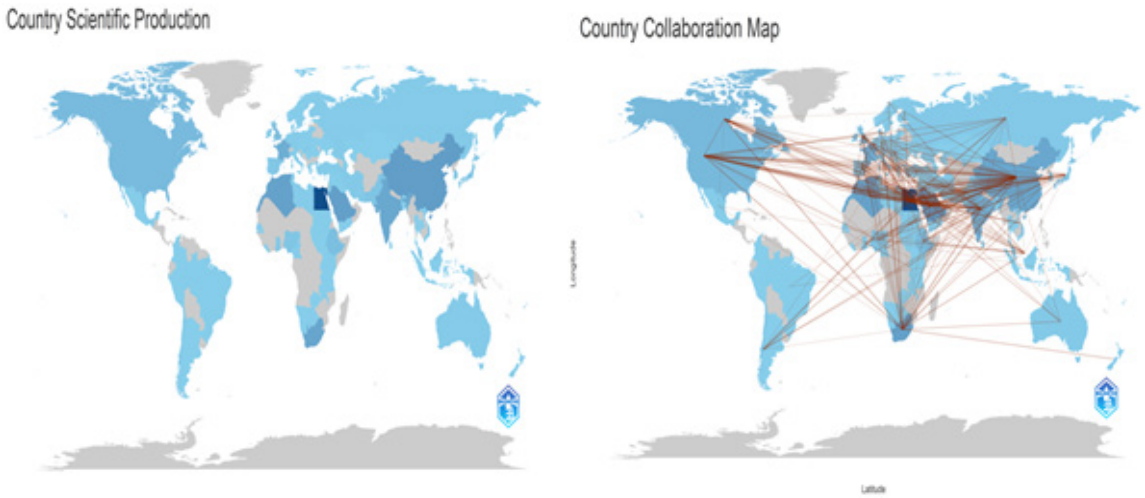


Figure 11: country production (left) and country collaboration map (right)

4.6. Content Analysis

The process of revealing the intellectual structure of two documents that have comparable referencing patterns refers bibliographic coupling and both bibliographic couples have similar content (Kessler, 1963). As anticipated, "electric vehicle" is the strongest term, according to Figure 12. The less research that has been done on a keyword, the smaller the keyword on the network diagram. Researchers will find this material very useful in determining the novelty and originality of their next studies.

Figure 12: Word Cloud

4.7. Thematic Analysis

Co-word analysis, as Callon et al. (1983) stated, looks at how frequently a keyword appears in a group of articles that demonstrate the conceptual or thematic structure of the literature. Thematic analysis is another way that this technique is used to identify the most important research fronts and project future

research (Singh et al., 2023). Thematic Map Analysis, as presented in Figure 13, visually represents the main themes in EV research and is organized by its relevance and development degree. Motor Themes (Upper Right Quadrant) are characterized by high development and relevance. Lithium-ion batteries theme highlights the critical role of battery technology in EV development.

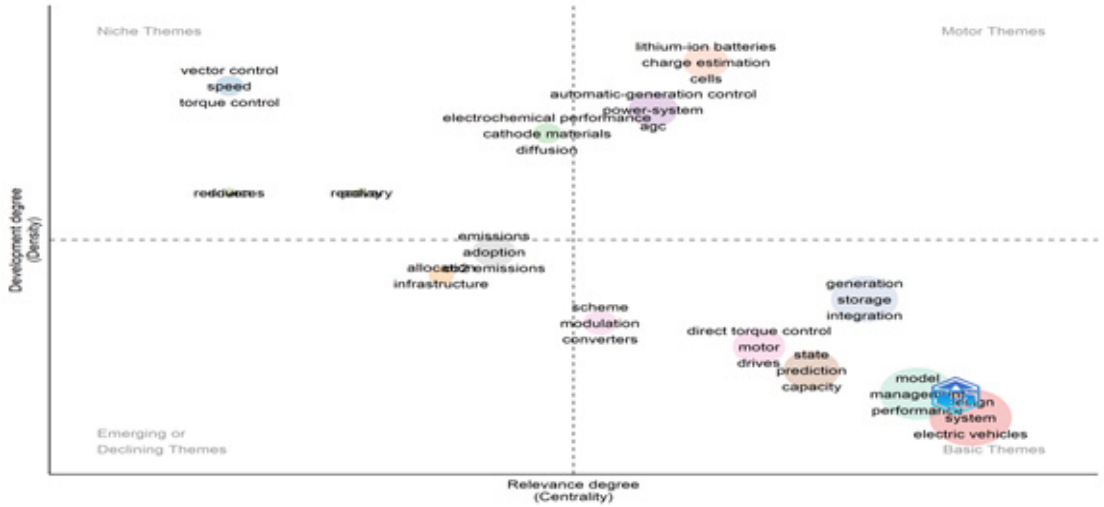


Figure 13: Thematic Map

Basic Themes (Lower Right Quadrant) are well-developed and fundamental but with moderate relevance. They are essential building blocks in the field. The other themes include electric vehicle, design, system, model, optimization, management, energy, hybrid storage, state prediction, capacity. Niche Themes (Upper Left Quadrant) are highly specialized and developed but have lower centrality in the field. They often represent advanced or emerging areas of research. Lithium-ion batteries, cells, automatic-generation control, management system, power system, and AGC: Although these themes overlap with motor themes, they are seen here in a more specialized context. These themes represent cutting-edge research or specific applications within the broader EV field.

Optimization and Performance: The focus on "optimization," "design," and "model" suggests that researchers are continually seeking ways to improve the overall efficiency and performance of EVs. This scenario includes optimizing powertrain components and vehicle dynamics. Moreover, within Environmental Impact and Adoption, the presence of themes like "emissions," "CO2 emissions," and "adoption" indicates a growing interest in the societal and environmental impacts of EVs. Understanding barriers to adoption and quantifying environmental benefits are important research areas. Specialized Research Areas show that the niche themes reveal specialized research efforts in advanced battery materials and electrochemical performance, which are crucial for next-generation EV technologies.

4.8. Co-citation and Co-occurrence

Co-citation analysis can be used to know how research in the chosen field has developed from many angles and how those perspectives relate to one another (Hasan et al., 2023).The number of citations and co-citations are indicated by node's size and line width, respectively. Mentioned journals' same color suggested that their research trajectories were comparable (He et al., 2020).

Figure 14: Co-citation Network Map

Figure 14 represents a bibliometric analysis of academic publications, visualized as a network map. The map displays clusters of nodes, each representing individual studies or papers, which are connected by lines indicating citations or references among them. Size of the nodes indicates the significance or impact of publications, with larger nodes representing more frequently cited works.

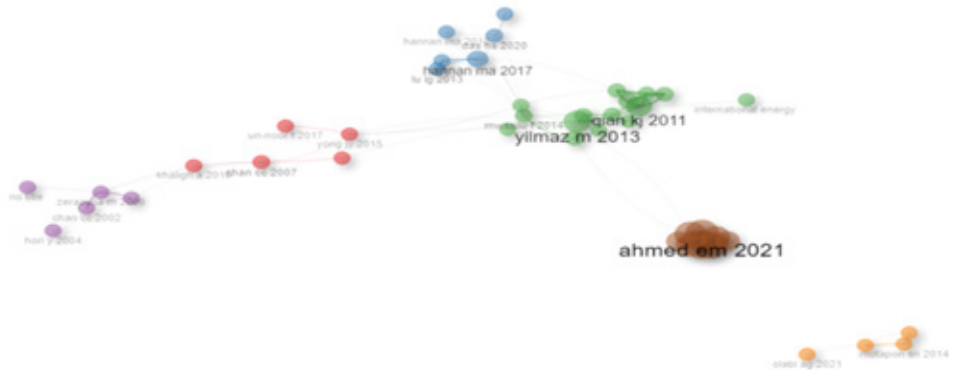


Figure 15: Co-occurrence

The co-occurrence analysis and relationship between EVs and other fields are displayed in Figure 15 (right). To create this co-occurrence network, the writers utilized every term from 1058 articles, including index and author keywords. The figure depicts the relationships among key concepts and keywords in a specific research field. The nodes represent keywords or terms frequently used in the literature. Size of each node indicates the prominence and frequency of keyword's occurrence in the dataset. Larger nodes signify more frequently occurring keywords. The nodes are color-coded into clusters, with each color grouping keywords that often appear together, indicating related subtopics within the broader research field. Central keywords like "design," "system," "electric vehicles," and "optimization" are centrally located and larger, indicating they are central themes in the research field being analyzed.

4. Discussion

Bibliometric analysis has been used in research across a wide range of fields (Hasan et al., 2023; Kim & Park, 2025). This article uses Bibliometric analysis to present various topics of research on EVs adoption from 2004 to 2023, based on data referred from the Web of Science database. According to the data, there was a small amount increase in EV publications between 2004 and 2013, but starting in 2014, the number of publications increased quickly, even with over 300 articles published annually. Using the quantity of publications and citations as metrics, the study examined distinguished writers, journals, organizations, and nations in relation to EVs adoption in Africa. The co-occurrence analysis was applied to determine the most often occurring terms, which were determined using author keywords. Terms like automatic-generation control, reconfiguration, and distribution-systems are highly impactful and central

topics to the field suggesting these are critical and influential areas of research.

5.1. Comparison with Global Trends

Globally, the production of EVs is increasing at an increasing rate and many countries from any corner of the world have access to import or assemble them locally. Regarding to clean energy technologies, there is significant variability across different EV technology areas. Start-ups for EVs are predominantly concentrated in the United States, Europe or China. About 70% of the venture capital investments in startups developing electric cars were made in China, 20% in the United States and 10% in Europe during 2018-2023 period (IEA, 2024). This shows that the share of Africa, with more than 18% of world's population, is very insignificant (less than 1%) though its potential for renewable energy is abundant.

Price of EVs in China was only 10% greater than fuel vehicles contributions compared with 45-50% on average in other main markets in 2021 (IEA, 2022b). Financial incentive policy measures in China significantly influence consumers' EVs adoption intention (Liao, 2021). Numerous countries worldwide, such as Norway (topping 80% of sales in 2021 and more than 90% in some months (Gopal & Anand, 2022)) and South Africa, have applied incentive policy to encourage mass EVs adoption for addressing energy scarcity and environment sustainability challenges (Nel & Inglesi-Lotz, 2022; Hasan, 2021). Norway is the per capita global leader and one of the top countries in the markets for clean energy vehicles due to government incentives. Low electricity prices are the first good condition. Hydropower generation accounts for 96% of the electricity in Norway (Morgan, 2020). Charging infrastructure is one of the barriers to EVs widely adoption. Kumar et al. (2021) stated in their research that EV charging stations market in the world is estimated to reach US$64.4 Billion by 2027 from US$7.4 billion in the year 2020 with a growth rate of 36.6% during the years. This may not be easily affordable to the low income countries in Africa but allocating significant resources to this sector will have a big and lasting cumulative economic, environmental and health effect.

The economic effect of EVs can be achieved when electric power is generated from renewable source like Norway does. Otherwise, in some countries like South Africa, the GHG emission is almost equal in fuel vehicles and EVs. Nonetheless, the entire EV cycle is taken into account when calculating energy efficiency. The findings demonstrate that EVs cannot reduce emissions or consumption when the share of energy from coal-fired power generation remains constant (Yao et al., 2023). On the other hand, countries in Africa like Ethiopia are giving a due attention and launching grand projects to hydropower, wind and geothermal renewable energy sources.

5.2. Insights and Implications for Various Stakeholders

This bibliometric analysis offers crucial insights for stakeholders involved in EV adoption in Africa. To policymakers the study emphasizes the need for strong policies to expand EV charging infrastructure and provide incentives for both manufacturers and consumers. While some research (e.g., Shanyong et al. (2018)) suggest financial incentives have limited impact on adoption intentions, others like Cruz-jesus et al. (2023), Nel & Inglesi-Lotz (2022) and Kwon et al. (2020) support their effectiveness in boosting EV adoption. Effective policymaking is essential to address barriers such as range anxiety and high initial costs. Insights into frequently researched topics and technological advancements can also guide manufacturers in aligning their R&D efforts with market demands. Recent trends show

increased focus on "charging stations," "energy storage," and "energy management strategy," alongside the dominant topic of "electric vehicles." Understanding these trends helps manufacturers innovate and remain competitive. Moreover, the study highlights the need for further research on behavioral aspects of EV adoption in Africa, as current research predominantly focuses on technical and environmental issues. This presents opportunities for exploring new areas and contributing to a more comprehensive understanding of EV adoption. On the other hand, investors and financial institutions can benefit from this study. The analysis identifies promising investment areas, such as integrating renewable energy with EV infrastructure and sustainable transportation solutions. This can guide investment decisions and support the development of innovative and sustainable technologies.

6. Limitations and Future Research

Reliance on the Web of Science database may miss some relevant publications. Future research could incorporate additional databases like Scopus and other relevant databases to provide a more comprehensive view of EV research in Africa. Countries in Africa like Ethiopia, which has a big potential of generating renewable energy, have to give a due attention to researches in EVs adoption including expansion of charging infrastructures and a significant reduction of blackouts. Future research should also explore the social, economic and cultural factors affecting EVs adoption in Africa, an area identified as under-researched. Comparative studies between African countries and other developing regions could provide valuable lessons and best practices.

7. Conclusion

This bibliometric analysis on EVs adoption in Africa during 2004-2023 reveals a growing body of research with significant contributions to policy, economic, and technological aspects. It has provided a comprehensive overview of the research landscape on EV adoption in Africa from 2004 to 2023. Key findings include: the rapid increase of number of research in recent years, with significant contributions from Egypt and strong international collaborations. However, several gaps remain, particularly in geographic coverage, longitudinal analyses, consumer behavior, comparative studies, and the integration of renewable energy. Addressing these gaps can provide a more holistic understanding of EV adoption in Africa and support the development of effective strategies for sustainable transportation. This study's contributions are multifaceted. It maps the existing research and provides actionable insights for policymakers, manufacturers, researchers, and investors. By identifying trends and gaps, it lays groundwork to future R&D in the field of EVs in Africa. Eventually contributing to the world’s effort to fight climate change and encourage sustainable transportation.

In conclusion, as Africa continues to develop its infrastructure and regulatory frameworks, the findings from this study can guide stakeholders in making informed decisions that will foster the growth of the EV market in the region. From unexpected results of this article, the highest number of EVs in Africa is found in South Africa but the highest number of publications is from Egypt. Countries with higher EV adoption tend to have more research output related to EV technology and infrastructure. This trend is driven by the need for advancements in battery technology, charging infrastructure, and energy management strategies, which are crucial for the widespread adoption of EVs (IEA, 2024). The study's impact lies in its potential to influence policy, drive innovation, and encourage further research, thus playing a pivotal role in the transition towards a sustainable future.

8. Declaration of Interest Statement

The authors declare that no conflicts of interest are associated with the manuscript "Charging Ahead: Key Drivers and Barriers to EV Adoption in Africa – A Bibliometric Analysis." The research was conducted independently and was not influenced by any financial, commercial, or personal relationships that could be perceived as potential conflicts of interest. The authors have no relevant financial or non-financial interests to disclose. This declaration confirms the integrity and transparency of the research process, ensuring that the findings presented in this manuscript result from unbiased analysis and reflect the authors' genuine academic intentions.

Takeaways

There is significant increase in EV research publications in Africa post-2014, aligning with global environmental policies.

• Key barriers identified include inadequate charging infrastructure, high costs, and range anxiety among African consumers.

• Recent focus on integrating renewable energy sources with EV infrastructure to leverage Africa's abundant hydro, solar and wind resources.

• Africa's underrepresentation in global EV research, particularly in consumer behavior and social acceptance studies

• EVs have a potential of significant fuel importing cost reduction and they are economical to countries which have big renewable energy resources.

• Creating green mind-set awareness to the people at large in the continent enhances the accelerated adoption of these sustainable vehicles.

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