SUSTAINABLE URBAN TRANSFORMATION: THE CONNECTION BETWEEN ELECTRIC MOBILITY AND SMART GRID

TRANSFORMAÇÃO URBANA SUSTENTÁVEL: A CONEXÃO ENTRE MOBILIDADE ELÉTRICA E REDES INTELIGENTES

TRANSFORMACIÓN URBANA SOSTENIBLE: LA CONEXIÓN ENTRE MOVILIDAD ELÉCTRICA Y REDES INTELIGENTES

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ABSTRACT

The integration of electric mobility with Smart Grids represents a transformative strategy for the development of sustainable urban systems, characterized by a reduced carbon footprint and high energy efficiency. This article carries out a systematic review with a bibliometric approach on the intersection between these two concepts, exploring not only the operational and environmental advantages, but also the social and economic implications of this synergy in building smart cities. The results indicate that the combination of electric mobility and Smart Grids is a rapidly growing area of study, with a significant increase in publications in high-impact scientific journals. Authors from globally renowned institutions have contributed to the consolidation of this field of research, reinforcing its relevance in the context of sustainable urban policies. Furthermore, an analysis of the literature reveals that Smart Grids, by incorporating new communication and information technologies, not only enable the large-scale adoption of electric mobility, but also promote the integrated and efficient management of urban infrastructure. This interconnectivity between systems allows for better optimization of the use of resources, as well as supporting the transition to more sustainable and resilient urban mobility.

KEYWORDS

Electric Mobility Integrated. Smart Infrastructure. Multi-Level Adoption.

RESUMO

A integração da mobilidade elétrica com as Smart Grids representa uma estratégia transformadora para o desenvolvimento de sistemas urbanos sustentáveis, caracterizados por uma pegada de carbono reduzida e alta eficiência energética. Este artigo realiza uma revisão sistemática com abordagem bibliométrica sobre a interseção entre esses dois conceitos, explorando não apenas as vantagens operacionais e ambientais, mas também as implicações sociais e econômicas dessa sinergia na construção de cidades inteligentes. Os resultados indicam que a combinação de mobilidade elétrica e Smart Grids é uma área de estudo em rápido crescimento, com um aumento significativo de publicações em periódicos científicos de alto impacto. Autores de instituições renomadas globalmente têm contribuído para a consolidação desse campo de pesquisa, reforçando sua relevância no contexto das políticas urbanas sustentáveis. Além disso, a análise da literatura revela que as Smart Grids, ao incorporar novas tecnologias de comunicação e informação, não apenas viabilizam a adoção em larga escala da mobilidade elétrica, mas também promovem uma gestão integrada e eficiente

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da infraestrutura urbana. Essa interconectividade entre sistemas permite uma melhor otimização do uso de recursos, além de suportar a transição para uma mobilidade urbana mais sustentável e resiliente.

PALAVRAS-CHAVE
Mobilidade Elétrica Integrada. Infraestrutura Inteligente. Adoção Multinível.

RESUMEN
La integración de la movilidad eléctrica con las Smart Grids representa una estrategia transformadora para el desarrollo de sistemas urbanos sostenibles, caracterizados por una huella de carbono reducida y una alta eficiencia energética. Este artículo realiza una revisión sistemática con enfoque bibliométrico sobre la intersección entre estos dos conceptos, explorando no sólo las ventajas operativas y medioambientales, sino también las implicaciones sociales y económicas de esta sinergia en la construcción de ciudades inteligentes. Los resultados indican que la combinación de movilidad eléctrica y Smart Grids es un área de estudio en rápido crecimiento, con un aumento significativo de publicaciones en revistas científicas de alto impacto. Autores de instituciones de renombre mundial han contribuido a la consolidación de este campo de investigación, reforzando su relevancia en el contexto de las políticas urbanas sostenibles. Además, un análisis de la literatura revela que las Smart Grids, al incorporar nuevas tecnologías de comunicación e información, no sólo permiten la adopción a gran escala de la movilidad eléctrica, sino que también promueven la gestión integrada y eficiente de las infraestructuras urbanas. Esta interconectividad entre sistemas permite optimizar mejor el uso de los recursos, así como apoyar la transición hacia una movilidad urbana más sostenible y resistente.

PALABRAS CLAVE
Movilidad eléctrica integrada. Infraestructura inteligente. Adopción multinivel.

1. INTRODUCTION

At present, numerous automotive manufacturers and other key stakeholders are channeling substantial resources into the advancement and mass production of electric vehicles, positioning electric mobility as a central topic in global discourse and a significant driver of policy-making and political decision-making processes (Liu et al., 2013; Morte, 2016; Santos et al., 2021). Despite this progress, the establishment of a robust and efficient recharging infrastructure continues to be one of the pivotal challenges that must be addressed to facilitate the widespread dissemination of this transformative technology, which holds the potential to revolutionize urban mobility on a global scale (Ala et al., 2020).

Consequently, it becomes imperative to reconfigure and modernize the power grid to support the integration of novel technologies and accommodate the evolving load profiles that accompany electric mobility. In this regard, Smart Grids are emerging as a crucial innovation within global electricity networks (Santo et al., 2015), offering an advanced and intelligent infrastructure that can seamlessly integrate and efficiently manage the growing demands for electrical energy in a sustainable manner (De Abreu, D'Agosto and Marujo, 2024).

The transition to a low-carbon society necessitates significant advancements in complementary domains: renewable energy generation and electric mobility can only realize their full potential through the deployment of Smart Grids, which are indispensable for managing the complexities and variabilities inherent in these emerging technologies (Hu et al., 2016). Moreover, the integration of these intelligent networks not only enhances the efficiency of electric vehicle recharging but also fortifies the stability and resilience of the power grid, enabling dynamic and real-time coordination between energy production and consumption. This capability is essential for ensuring the sustainability and long-term viability of the urban environments of the future.

Smart Grids seek to transform the traditional electricity network using advanced automatic control and communication techniques and other forms of information technology. The main objective of a Smart Grid is to deliver the optimum amount of information and load control to customers, distributors and grid operators in order to reduce system demands and costs while increasing energy efficiency (Cecati et al., 2010). This study aims to carry out a literature review with a bibliometric approach to identify studies that address the benefits of electric mobility, which enables and is enabled by Smart Grid, through direct searches in the Web of Science database. The specific objectives are: (i) to present the evolution of publications and citations over the years; (ii) to identify the main journals and countries that publish the most studies on the subject; (iii) to verify the most recurrent keywords, including the interconnection network between them; and (iv) to provide an overview of the benefits of implementing the two technologies concurrently.

In order to fulfill its objectives, this study is structured as follows. Section 1 deals with the context, importance and objectives of the study. Section 2 deals with the methodological procedure used to conduct bibliographic searches, with a focus on bibliometrics. Section 3 discusses bibliometric analysis. Section 4 describes some of the main results of the research included in the research repository, highlighting the main potential of the union between electric mobility and the Smart Grid. Finally, Section 5 contains the final considerations, which contain recommendations for future studies.

2. METHODOLOGICAL PROCEDURE

This study consists of a literature review using a bibliometric approach to map the main studies dealing with the role of the Smart Grid in promoting electric mobility and vice versa. A growing number of studies have used bibliometric techniques in various disciplines to track the state of the art of a field and its evolution over time. In this sense, the search terms, inclusion and qualification criteria used, as well as the details for the search and extraction of the database, are presented in Table 1, where TS = Topic, which means the words that are searched in the titles, abstracts and keywords of the studies.

It was decided to use keywords in English due to the greater number of relevant studies in English. In addition, even studies published in other languages, such as Portuguese, Spanish or French, mostly have at least an Abstract in English. It is also worth noting that the keyword Smart Grid was combined with variations of electric mobility to further increase the sample coverage. It was decided to use the Web of Science databases, belonging to Clarivate Analytics, as the main search tool due to their diffusion in the academic community and the reliability of their selection standards (Ameen et al., 2018; Caviggioli and Ughetto, 2019). In addition, this database has satisfactory reach and coverage (Chen, 2010).

As a limitation, it is worth mentioning that the study used only one database (Web of Science) and did not consider publications in other databases such as Science Direct, Scielo and Scopus. It is also important to note that search terms can influence the results, so the articles included in the research repository are limited by the database and search terms used.

Criteria	Description
Topicst	TS= (Smart Grid* AND e-mobility) OR TS= (Smart Grid* AND electric vehicle*) OR TS= (Smart Grid* AND electric mobility)
Database	Web of Science
Indexes	SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI
Inclusion	(I) Time of coverage: all years of the database (1945 - 2021); and (II) Fit with the proposed objective.
Qualification	(I) Does the research present a well-founded literature review? (II) Does the study present technical innovation? (III) Are the contributions discussed? (IV) Are the limitations explicitly stated? and (V) Are the results and conclusions consistent with the pre-established objectives?
Date of Search	May 09, 2021, at 7:00 p.m.

Table 1: Description of the search strategies.

3. BIBLIOMETRIC RESULTS

The research of the Web of Science database revealed that a significant 2,806 publications were suitable for inclusion in the research repository, i.e. they met the inclusion and qualification criteria (quality and applicability). Figure 1 shows the evolution of publications on the subject over the years. This analysis is essential for assessing the level of expansion of the topic, as well as new opportunities for studies. Figure 1 shows that the first publication was recorded in 2008, with only 2 (0.07%) publications, which shows that the subject is extremely current. In addition, the subject continues to expand, peaking in 2018 with 352 (12.54%) publications.

It is also pertinent to evaluate the articles by source of publication, in order to identify which scientific journals and congresses are most interested in the subject. This allows researchers to direct their publication efforts towards scientific dissemination media that have a direct focus on the subject under study, avoiding the necessary waste of time. In this sense, Figure 2 shows the journals with a publication volume greater than or equal to 36. It shows that the publication sources that most deal with the subject are: IEEE - Transactions On Smart Grid, with 125 publications, Energies, with 112 publications, and IEEE - Power And Energy Society General Meeting PESGM, with 92 publications. It should also be noted that a total of 1,352 sources of publication on the subject were identified, which indicates a significant participation of the topic in the scope of relevant journals and congresses.

It was also considered pertinent to assess the countries of origin of the authors' educational institutions that have produced the most relevant articles on the subject. This shows which countries are doing the most research on the subject under investigation, as well as demonstrating the lack of investment in other countries. The countries with the highest number of publications are shown in Figure 3, which was developed using Excel software.

Figure 3 shows that most publications are concentrated in the United States of America, with 578 publications, followed by the People's Republic of China with 467 publications, and Canada with 217 publications. European countries such as Italy (178), Germany (153), and England (133) also have significant contributions, along with Australia (153) and India (165). These numbers indicate a strong presence of research in developed countries, reflecting their robust research infrastructures and funding capabilities.

Interestingly, many developing countries are also making notable contributions. Brazil, for example, currently ranks eighteenth with 51 publications, highlighting its growing academic interest and strengthening research infrastructure. Other developing countries such as Iran (128), South Korea (94), Turkey (43), Pakistan (38), and Malaysia (32) have shown substantial engagement in research, contributing valuable perspectives and findings. This demonstrates significant and growing involvement of developing nations in the global research landscape, approaching their more developed counterparts.

Overall, the participation of 89 countries with at least one publication on the subject highlights the collaborative and global nature of scientific research. Countries with fewer publications, such as Bangladesh, Morocco, and Vietnam, still add to the diversity of research perspectives. This global engagement is crucial for addressing complex transnational challenges and promoting innovation through a rich fabric of cultural and intellectual diversity. The combined efforts of developed and developing countries enhance collective knowledge and advance the field in a more inclusive and comprehensive manner.

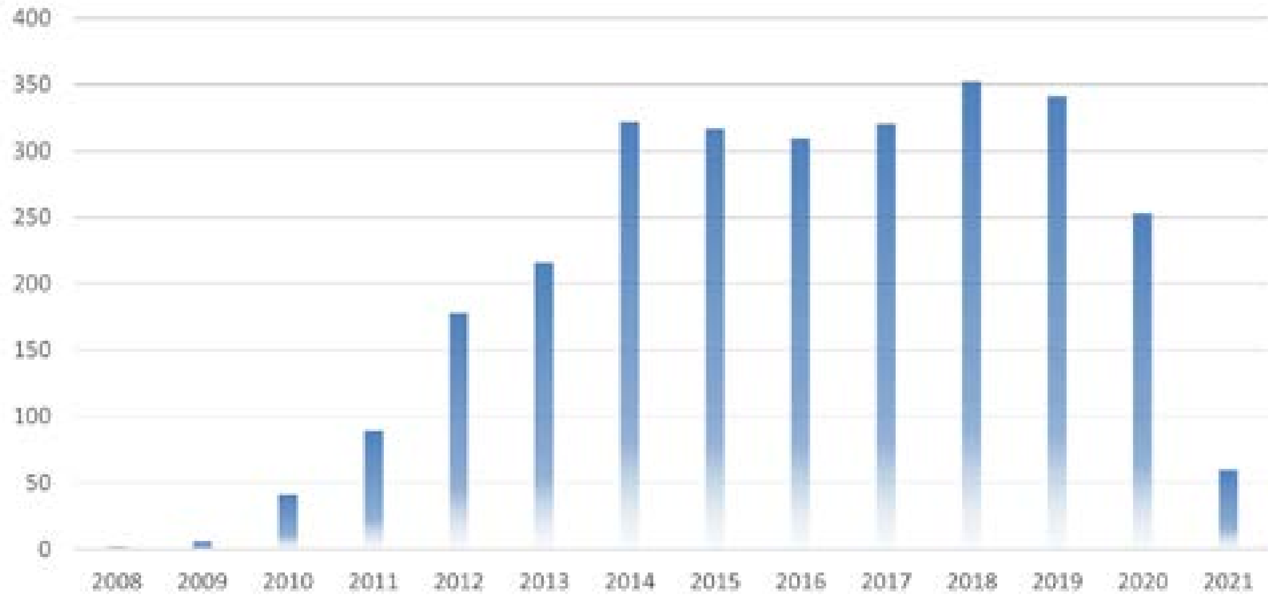

Figure 1: Evolution of publications by year.

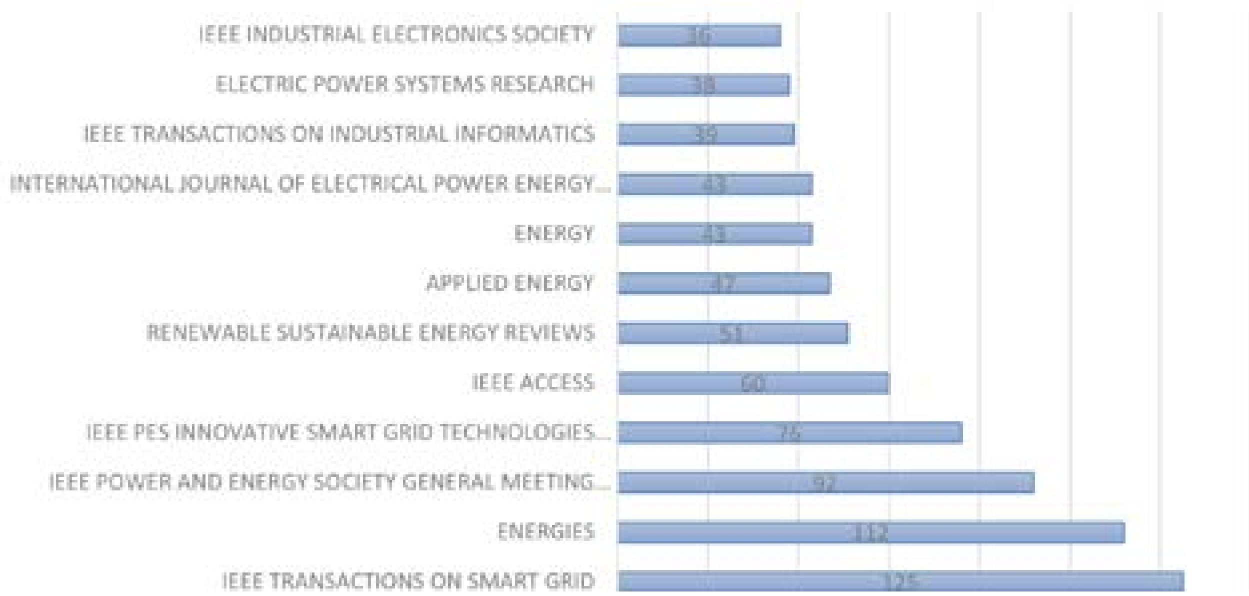

Figure 2: Main sources of publication of studies.

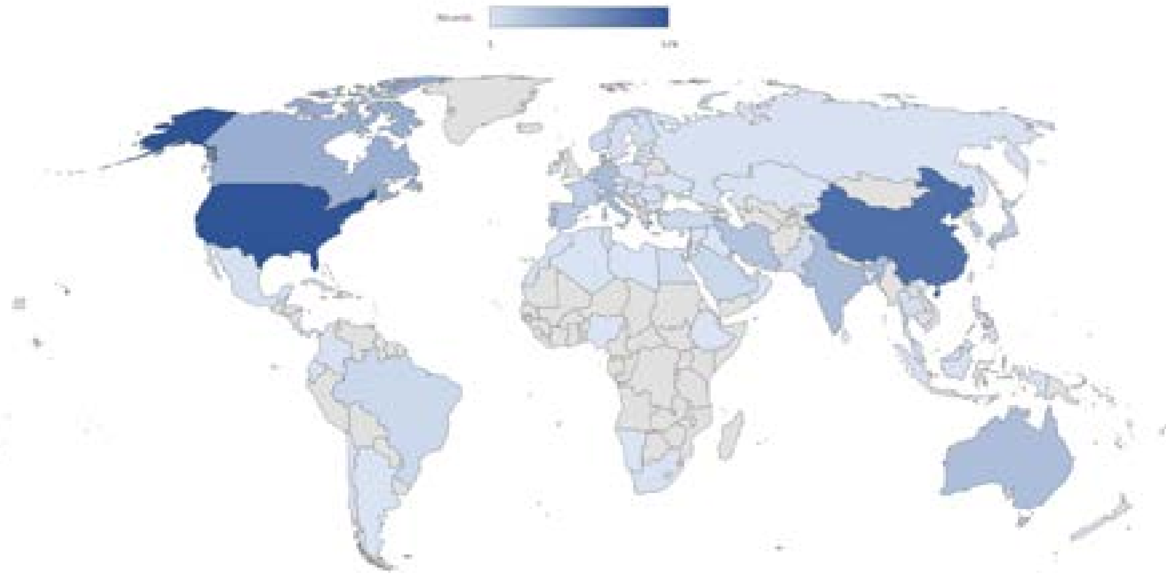

Figure 3: Main countries.

We also believe it is interesting to evaluate the main keywords found in the articles included in the research repository, as identified in the interconnection network between the keywords shown in Figure 4, developed with the help of the VOSviewer software. This strategy allows researchers to more easily find studies directly related to the subject under investigation, as well as to identify new research directions that can be taken.

In Figure 4, the network visually represents several key aspects: the prominence of specific keywords, indicated by the size of each sphere representing them; the relationships and interconnections between these keywords, illustrated by the connections between spheres; and the temporal relevance of these keywords, represented by the color coding of each sphere.

This visualization provides insights into various facets of research or discussion within the domain. It prominently features keywords related to advanced vehicle technologies, including plug-in electric vehicles, lithium-ion batteries, and power electronics. These technologies are pivotal in the development of sustainable transportation solutions and are central to ongoing research and innovation efforts worldwide.

Moreover, the network diagram includes keywords associated with electric charging infrastructure, such as smart charging strategies, smart charging schedules, and considerations for managing electrical peak demand. These aspects are critical in optimizing the efficiency and reliability of electric vehicle charging systems, addressing challenges related to grid integration and user convenience.

Additionally, the diagram highlights keywords related to network and user security, underscoring the importance of safeguarding data and ensuring secure interactions within smart mobility ecosystems. Terms like privacy, authentication protocols, and blockchain technology signify ongoing efforts to enhance cybersecurity and protect user information in the context of connected vehicle systems.

In summary, Figure 4 serves as a comprehensive visual representation that elucidates the multidimensional landscape of research and development in the field of advanced mobility technologies. It not only showcases the focal points of current discussions and innovations but also underscores the interconnectedness of various technological and security-related considerations shaping the future of smart transportation systems.

Another crucial aspect of analysis pertains to the number of citations per year, illustrated in Figure 5. This analysis, alongside the evolution of publications across different years, provides valuable insights into the increasing interest and impact of the subject over time. Figure 5 demonstrates that the first citation appeared in 2010, marking a significant milestone just two years after the initial publication. Since then, the number of citations has steadily increased each year, reflecting a growing recognition and relevance of the topic within academic and research communities. Notably, the peak in citations occurred in 2020, with a remarkable count of 1,250 citations, underscoring a substantial culmination of interest and engagement in the subject matter.

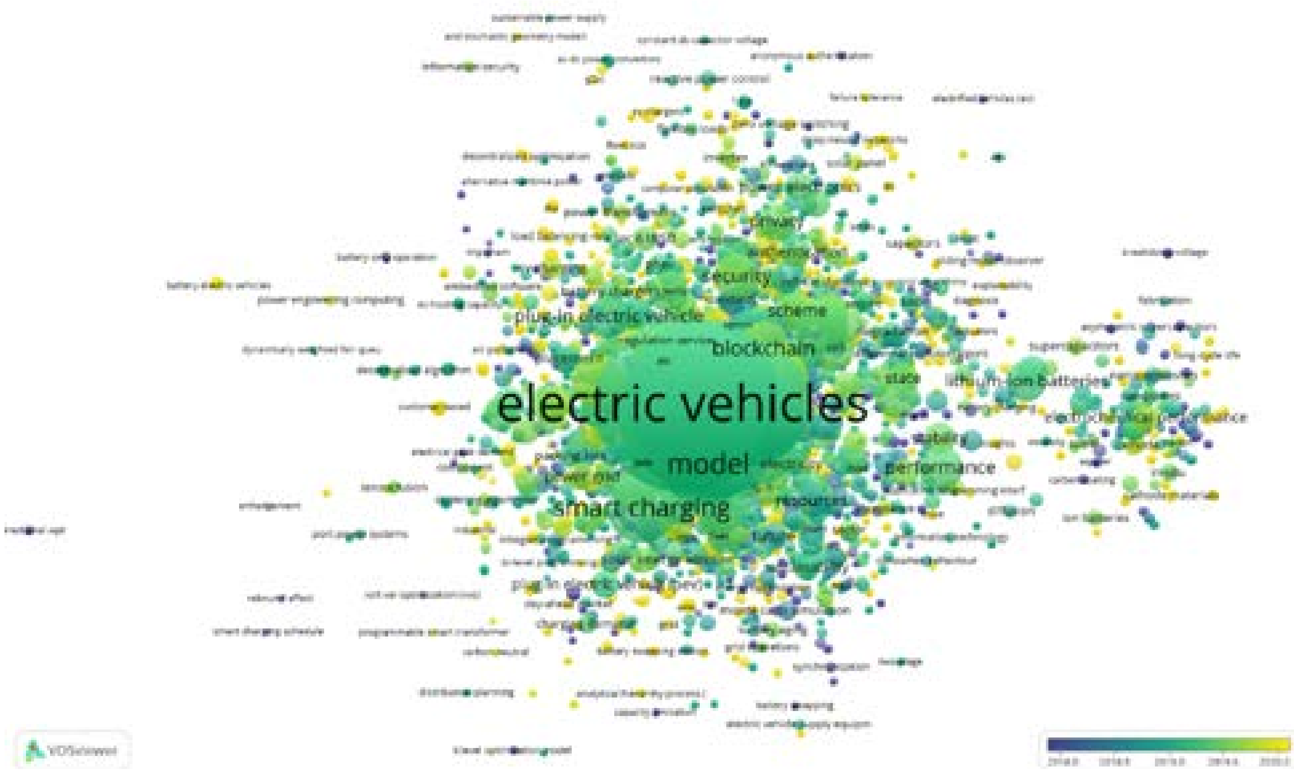

Figure 4: Main keywords.

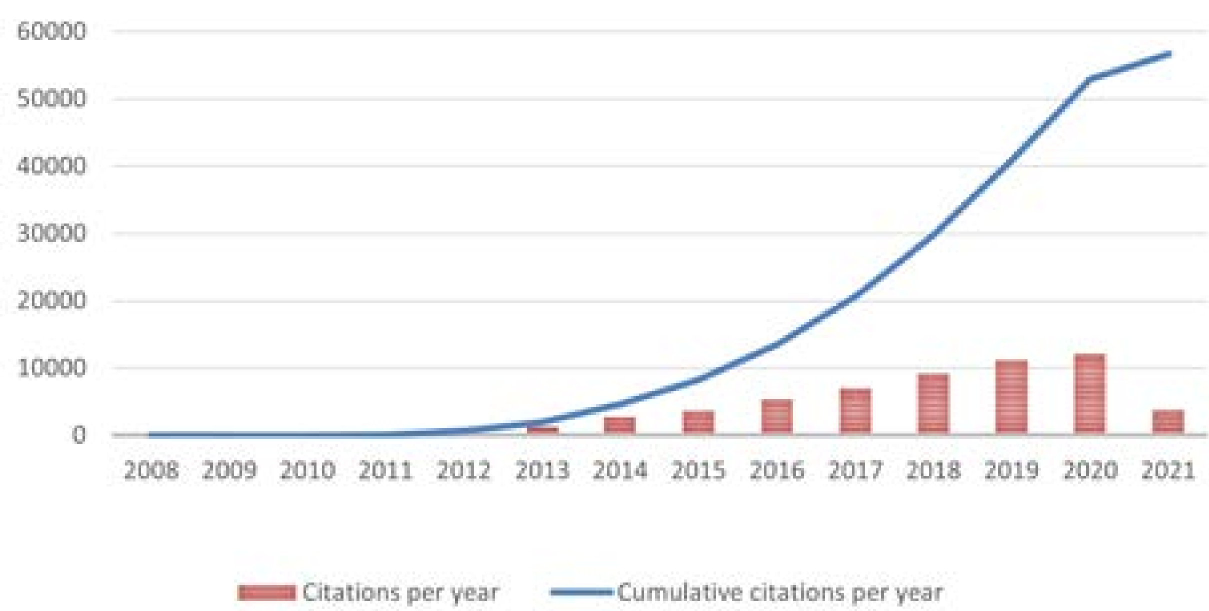

Figure 5: Evolution of citations by year.

This data reinforces the ongoing growth trajectory and sustained interest in the field. It highlights how research contributions have not only expanded but also garnered significant attention and acknowledgment within scholarly discourse. Such trends affirm the enduring importance and impact of the subject, motivating further exploration and advancement in related areas of study. It is also possible to determine the dispersion of citations of the most relevant studies in the database using Figure 6. It shows how the citations of each of the 10 most cited studies (TOP 10) are distributed over the years. The study by Deilami et al. (2011) is the most significant in the database, with a certain stability in citations from 2012 to the present day. Other publications such as Tie and Tan (2013) and Su et al. (2012) also occupy a considerable part of the graph.

Granados, 2012; Richardson, 2013). These characteristics are achieved through automated controls, modern communication infrastructure and energy sensing, monitoring and management technologies, which are related to the Internet of Things - IoT (Gungor et al., 2011).

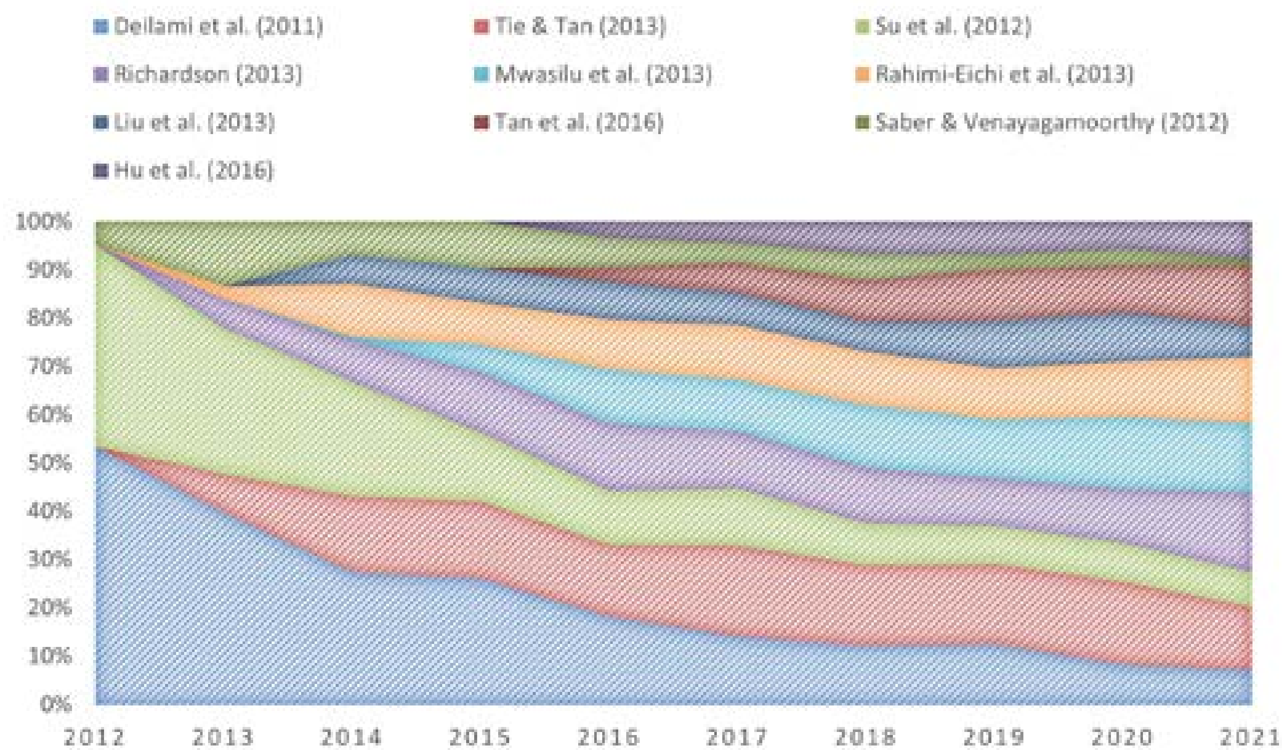

Figure 6: Distribution of citations of the most relevant studies by year (TOP 10).

4. ADVANTAGES OF INTEGRATING ELECTRIC MOBILITY AND THE SMART GRID

The modern network infrastructures employed in Smart Grids can play a key role in enabling innovative, sustainable and user-friendly urban services for all those involved in the business, allowing for energy efficiency, low carbon footprint systems and a more efficient city in terms of use (Hu et al., 2016), essential aspects for the development of a Smart City. Smart Grid is thus an electricity network capable of integrating actions by all stakeholders (e.g. customers, suppliers, government, etc.) in order to enable the recharging of electricity in a sustainable way (Curiale, 2014).

Smart grids are essential for integrating multiple forms of distributed generation of electricity from renewable sources, diversifying the energy matrix, reducing transmission losses and improving the reliability, security and efficiency of the power system (Carvalho, Perez and

The irregular availability of most renewable energy sources requires the storage of electricity, usually using dedicated batteries (De Abreu, D'Agosto and Marujo, 2024). With the help of advanced electricity system management systems based on the Smart Grid, batteries can be used to store electricity and act as a "rotating power reserve" when peak demand occurs, for example by using the resources of electric vehicles that are idle (Ala et al., 2020). In a complementary way, for electricity providers, the electrification of vehicles offers a way to solve peak demand by supporting the stability of the local grid, without having to intervene in distant power generation facilities, thus reducing the burden on the grid structure at peak times (Aziz, Oda and Ito, 2016; Hu et al., 2016).

In addition, when electric vehicles are progressively integrated into Smart Grids, large amounts of data and information will be available to everyone involved with infrastructure and communication systems, providing new opportunities for companies operating in the automotive sector, such as influencing the competitiveness, market shares, business models and marketing strategies of current car manufacturers (Ala et al., 2020).

According to Curiale (2014), Smart Grids must: (i) modernize the energy system through self-healing projects, automation, remote monitoring and control; (ii) inform and educate consumers about energy use, costs and alternative options, to empower them to make decisions autonomously about how and when to use electricity and fuels; and (iii) provide secure and reliable integration of renewable and distributed energy resources. All this adds up to a more reliable, sustainable and resilient energy supply infrastructure.

The Smart Grids vision combines the use of traditional technology with innovative digital solutions that make the management of the existing distribution network more flexible through more effective information exchange (Rahimi-Eichi et al., 2013). Electricity grids are renewed to better accommodate the flow of all energy sources, especially renewables, optimize electricity flows, enable new services such as electric mobility and active demand (Curiale, 2014, De Abreu, D'Agosto and Marujo, 2024). Thus, the connections between electric vehicles and the Smart Grid are illustrated in Figure 7.

In the scheme shown in Figure 7, developed by Dileep (2020), the grid operator (labeled ISO) receives electricity from its electricity suppliers/generators (wind power plants, solar power plants, hydroelectric power plants, etc.) and transmits it to the urban infrastructure (consumers/customers) via the Smart Grid. This energy transmission can be supplied to electric vehicles both at individual recharging points (homes, for example) and in parking lots that have collective recharging stations. It is worth mentioning that all types of electric vehicles such as bicycles, scooters, cars and buses can be charged via Smart Grids.

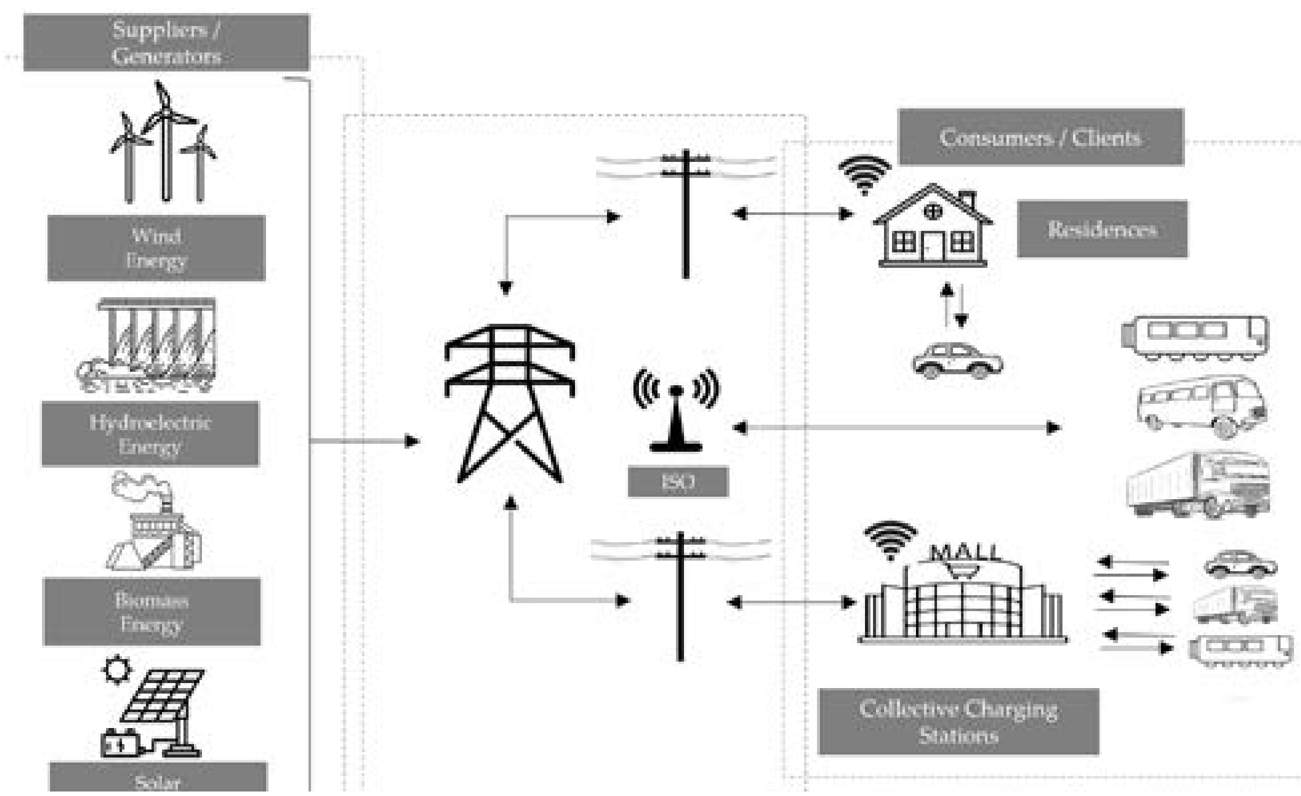

Figure 7: Structure of the relationship between the Smart Grid and electric mobility.
Source: Adapted from Dileep (2020).

The infrastructure for charging electric vehicles continues to expand. In 2019, there were around 7.3 million chargers worldwide, of which around 6.5 million were slow chargers for private light vehicles in single-family homes, multi-dwelling buildings and workplaces, due to benefits such as convenience, savings and a variety of support policies (such as preferential rates, incentives for equipment purchases and discounts) (International Energy Agency - IEA, 2020).

In addition, electric vehicles themselves can be used to store and subsequently supply electricity (in a bidirectional flow) when the system needs it and sends a control signal (Tan and Yong, 2016). This indicates that there are two possible types of energy interactions between the vehicle and the power grid: (i) G2V (Grid to Vehicle), which consists of a power grid supplying energy to the plug-in electric vehicle via a charging port; and (ii) V2G (Vehicle to Grid), in which a vehicle is able to supply energy back to the power grid, i.e. it stores energy that is used to compensate for peaks and valleys in electricity supply and demand and thus help optimize grid management (Mwasilu et al., 2014).

According to Dileep (2020), there are three main versions of the V2G concept, all involving an on-board battery, which are: (i) a hybrid or fuel cell vehicle; (ii) a battery-powered hybrid vehicle or a plug-in battery electric vehicle; or (iii) a solar vehicle. V2G technology can be employed, transforming each vehicle with its 20 to 50 kWh battery into a distributed load balancing device or emergency power source.

In addition to electricity suppliers, the company that owns the Smart Grid service and consumers/customers, other stakeholders also have an influence on the relationship between the Smart Grid and electric mobility, such as the government, regulatory bodies, society in general, the affected community, among others. The integration between electric mobility and the urban energy distribution network in a Smart Grid structure can favor the construction of a multi-stakeholder and multi-Internet ecosystem (Internet of Information, Internet of Energy and IoT) with cutting-edge computing resources supported, for example, by cloud-level services and with clean mapping between the logical and physical entities involved and their stakeholders (De Abreu et al., 2023; D'elia et al., 2015).

Figure 8 presents the necessary elements for effective integration between Electric Mobility Systems, including the interoperability of charging infrastructures, the compatibility of vehicles with different charging standards, and efficient communication between vehicles, power grids, and energy management systems. Additionally, it highlights the importance of cybersecurity, intelligent data management, and collaboration among manufacturers, energy providers, and regulatory authorities.

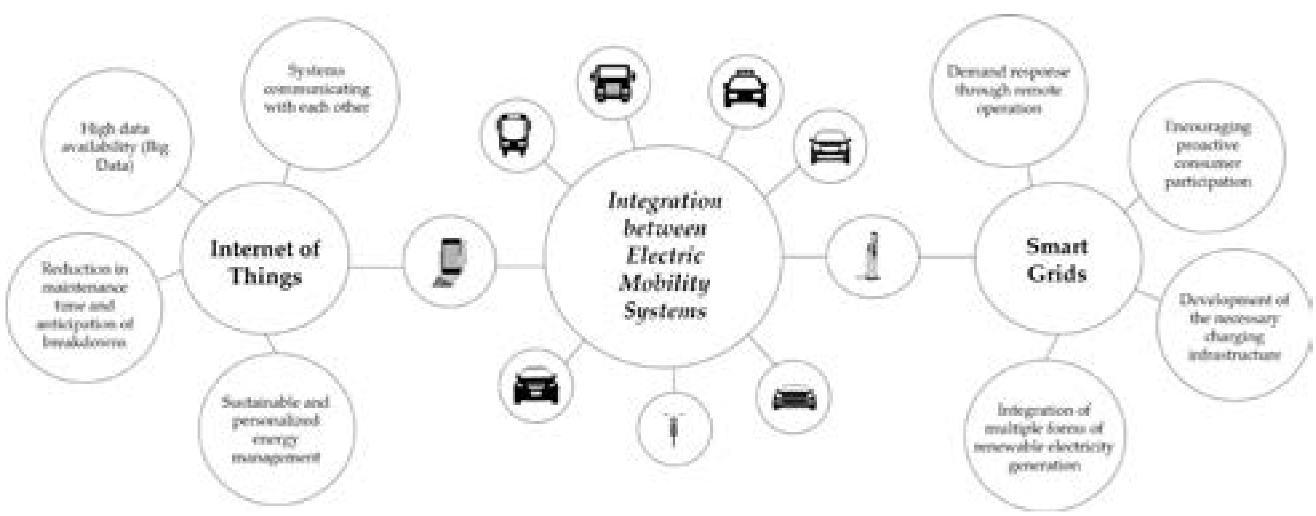

Figure 8: Elements for effective integration between Electric Mobility Systems.

It should also be noted that the Smart Grid has the potential to promote the multi-level adoption of electric mobility because, through the new communication and information technologies implemented, there is the possibility of better interaction between the systems that make up the urban mobility infrastructure, allowing various levels of access to transport facilities, which enable the same user to make use of different levels of electric vehicles (bicycles, scooters, cars, buses, etc.) in an integrated and intelligent way in cities of different sizes and technological profiles (De Abreu et al., 2023).

A Smart City that combines multi-level electric mobility and Smart Grids can help overcome the limits and contradictions of the current urban development model, characterized by a poor connection between the different resources available. However, it should not just be seen as a list of solutions, but as a multi-year holistic approach, therefore based both on planning projects and investments with a medium to long-term time horizon, and on involving multiple stakeholders (Ruggieri et al., 2021).

Through this multi-level adoption of electric mobility, the customer service system as a whole is expected to improve in terms of service level (accessibility, travel time, comfort, safety, etc.) and with tariff integration and service cost reduction (De Abre et al., 2023; De Assis et al., 2022a; De Assis et al., 2022b; Da Costa et al., 2022). In an efficient, open and constantly evolving Smart Grid system, customers become protagonists thanks to the use of electronic supports that make consumption transparent, encourage active participation in the energy market, improve the level of service and promote the conscious use of energy (Curiale, 2014).

Thus, according to Dileep (2020), the Smart Grid has the potential to: (i) reduce electricity prices paid by consumers; (ii) improve accessibility to services by consumers; (iii) increase the opportunities for choice of supply and information conveyed to the consumer; (iv) integrate renewable/unconventional distributed energy resources; (v) improve security by reducing the consequences and likelihood of natural disasters and man-made attacks; (vi) facilitate greater penetration of alternate sources of power generation; (vii) reduce loss of life and injury in grid-related events, thus reducing safety problems; (viii) improve overall efficiency by reducing energy losses and waste; and (ix) decrease environmental pollution by reducing greenhouse gas and air pollutant emissions and providing cleaner energy by promoting the deployment of renewable distributed energy resources.

According to the Department of Energy & Climate Change (Department of Energy & Climate Change, 2014), as the Smart Grid evolves, there will be more active roles for customers of different profiles - for example, domestic customers with smart meters can choose tariffs and make use of smart appliances that shift demand at peak times (for example, electric vehicles can be refueled at times with lower demand for energy and, consequently, a lower charge for energy consumption can be directed to the customer); large industrial and commercial customers can participate in a wide range of demand response and capacity market schemes, and small-scale generators can participate in demand response and capacity market schemes by adjusting exports to a grid.

Smart grids are thus the key to the success of a new idea of urban living: advanced, shared and sustainable (Mwasilu et al., 2014). In a smart, open and constantly evolving electricity grid system, customers become protagonists thanks to the use of electronic supports that make consumption transparent, encourage active participation in the energy market and promote the conscious use of energy (Curiale, 2014). These updated electricity grids with smart metering and monitoring capabilities, as well as two-way digital communication between supplier and consumer, have the capacity to predict and respond intelligently to the behavior and actions of all users connected to them, resulting in the efficient delivery of reliable, cost-effective data and sustainable electricity supply services (European Commission, 2011).

However, it is also worth mentioning that in order for all the aforementioned benefits to be met, it is necessary to increase the field of application of technologies by raising consumer awareness, especially among those who are unable to find relevant information or are exposed to confusing, untrustworthy or conflicting information about the use of electric vehicles, which reduces the rates of their diffusion and acceptance (Augenstein, 2015; Biresselioglu, Demirbag Kaplan and Yilmaz, 2018). This is because the ways in which individuals subjectively perceive technological innovation and how it can be integrated into their daily lives shape diffusion processes (Costa et al., 2021).

In this way, solutions to change the transportation habits and preferences of end users require an integrated approach, combining technological innovation, policy incentives, and user education (Künle and Minke, 2022). This approach involves the development and deployment of advanced electric vehicle technologies, improvements in battery efficiency, and the expansion of reliable charging infrastructure. Policy incentives, such as tax rebates, subsidies, and grants for both manufacturers and consumers, play a critical role in reducing the initial cost barriers and making electric vehicles more accessible (De Abreu, D'Agosto and Marujo, 2024).

User education is also essential, as it helps to increase awareness and understanding of the benefits of electric mobility, addressing common misconceptions and highlighting long-term savings and environmental impacts. Effective communication strategies, community engagement programs, and demonstration projects can further enhance user acceptance and encourage behavior change. When designing models to encourage users to make a faster transition to electric mobility, it is crucial to consider a range of constraints:

- Technical Constraints: These include the development of efficient battery technologies with longer life spans and shorter charging times, the establishment of a widespread and accessible charging infrastructure, and the integration of electric vehicles with smart grids and renewable energy sources.
- Economic Constraints: Addressing the high upfront costs of electric vehicles through financial incentives, subsidies, and financing options is vital. Additionally, the economic implications of transitioning from fossil fuels to electric energy, such as impacts on employment in traditional automotive industries and energy sectors, must be managed.
- Social Constraints: Understanding and addressing social resistance to change, influenced by factors such as cultural attitudes, habits, and perceived reliability of electric vehicles, is essential. Efforts should be made to engage communities, provide adequate information, and create positive experiences with electric mobility.

Moreover, successful implementation depends on the collaboration between various stakeholders, including government bodies, industry players, and the public. Government policies and regulations need to support innovation and infrastructure development, while industry stakeholders must focus on producing affordable and high-quality electric vehicles. Public participation and feedback can guide improvements and ensure that the transition meets the needs and preferences of end users. Ultimately, a holistic and well-coordinated approach that integrates these elements is key to achieving a sustainable and widespread adoption of electric mobility (Pavić, Pandžić, and Capuder, 2020).

5. FINAL CONSIDERATIONS

This work aims to collect, collate, and evaluate the main studies on the implementation of electric mobility in parallel with the development of Smart Grids through a bibliographic review with a bibliometric approach. The bibliometric results indicate that the subject continues to expand, with a significant increase in publications peaking in 2018 and a surge in citations in 2020, ten years after the first publications on the topic. Notably, high-impact journals have published extensive studies on this subject, with IEEE Transactions on Smart Grid being the most recurrent in the database, demonstrating its central role in this research area.

Furthermore, this article underscores the complementary nature of electric mobility and Smart Grids, highlighting their combined potential to drive the development of sustainable and intelligent cities. This synergy not only enhances the overall quality and efficiency of the energy system but also empowers users to play a pivotal role as active participants. Through vehicle-to-grid (V2G) technologies, users can even become electricity suppliers, contributing to grid stability and resilience. These advancements are integral to the realization of smart cities that prioritize sustainability, energy efficiency, and an improved quality of life for their residents.

Given the ongoing evolution of this field and the significant potential it holds, there is a pressing need for further research. In Brazil, in particular, research on this subject remains limited. Therefore, it is advisable to conduct more extensive studies, including both narrative and systematic bibliographical reviews, to deepen the understanding of the interaction between electric mobility and Smart Grids. Future research should focus on critical aspects such as network security, user safety, and practical applications, including case studies of Smart Grid and electric mobility projects currently in the design phase. These studies will provide valuable insights and guide the successful implementation of these technologies, ensuring their contributions to a sustainable and intelligent future.

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VHSA: conceptualization, formal analysis, investigation, methodology, project administration, visualization, writing - original draft and writing - review & editing.

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