Research, Society and Development, v. 13, n. 4, e7113445576, 2024
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v13i4.45576

Strategic Synergies Between Beyond 5G and Smart Grids for Sustainable Development

Sinergias Estratégicas Entre Além da 5G e Redes Inteligentes para o Desenvolvimento Sustentável

Sinergias Estratégicas Entre Más Allá del 5G y Smart Grids para el Desarrollo Sostenible

Received: 04/09/2024 | Revised: 04/15/2024 | Accepted: 04/16/2024 | Published: 04/19/2024

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Abstract
This article provides a comprehensive review of the intersection of beyond 5G and Smart Grids, focusing on the potential of Vehicle-to-Fog as an industrial alternative for addressing energy efficiency challenges in data processing. This study aims to investigate relevant publications and patents to understand the collaborative potential between 5G and Smart Grids. It explores establishing new regulatory standards within the 5G framework to facilitate decentralized data processing and remodel energy consumption patterns. The hypothesis suggests that decentralized 5G architecture and Smart Grids can be most effectively applied through Vehicular Fog powered by solar energy. A combined quantitative and qualitative methodology guides the exploration of publications and patents. The study concludes by advocating for new standards that embrace decentralized 5G data processing, emphasizing the potential of Vehicle-to-Fog and the future deployment of 6G technology in Smart Grids. These advancements can significantly enhance energy efficiency in the context of 5G and pave the way for future innovations.
Keywords: Beyond 5G; Smart grids; Technological innovation systems.

Resumo
Este artigo fornece uma revisão abrangente da intersecção além do 5G e das redes inteligentes, com foco no potencial do Vehicle-to-Fog como uma alternativa industrial para enfrentar os desafios de eficiência energética no processamento de dados. Este estudo tem como objetivo investigar publicações e patentes relevantes para compreender o potencial colaborativo entre 5G e Smart Grids. Explora o estabelecimento de novos padrões regulatórios no âmbito do 5G para facilitar o processamento descentralizado de dados e remodelar os padrões de consumo de energia. A hipótese sugere que a arquitetura 5G descentralizada e as redes inteligentes podem ser aplicadas de forma mais eficaz através da névoa veicular alimentada por energia solar. Uma metodologia combinada quantitativa e qualitativa orienta a exploração de publicações e patentes. O estudo conclui defendendo novos padrões que abranjam o processamento descentralizado de dados 5G, enfatizando o potencial do Vehicle-to-Fog e a futura implantação da tecnologia 6G em redes inteligentes. Estes avanços podem melhorar significativamente a eficiência energética no contexto do 5G e abrir caminho para inovações futuras.
Palavras-chave: Além da 5G; Redes elétricas inteligentes; Sistemas de inovação tecnológica.

Resumen
Este artículo proporciona una revisión exhaustiva de la intersección entre más allá de 5G y las redes inteligentes, centrándose en el potencial de Vehicle-to-Fog como una alternativa industrial para abordar los desafíos de eficiencia energética en el procesamiento de datos. Este estudio tiene como objetivo investigar publicaciones y patentes relevantes para comprender el potencial de colaboración entre 5G y Smart Grids. Explora el establecimiento de nuevos estándares regulatorios dentro del marco 5G para facilitar el procesamiento descentralizado de datos y remodelar los patrones de consumo de energía. La hipótesis sugiere que la arquitectura 5G descentralizada y las redes inteligentes se pueden aplicar de manera más efectiva a través de niebla vehicular alimentada por energía solar. Una metodología combinada cuantitativa y cualitativa guía la exploración de publicaciones y patentes. El estudio concluye abogando por nuevos estándares que adopten el procesamiento descentralizado de datos 5G, enfatizando el potencial de Vehicle-to-Fog y el futuro despliegue de la tecnología 6G en Smart Grids. Estos avances pueden mejorar significativamente la eficiencia energética en el contexto de 5G y allanar el camino para futuras innovaciones.
Palabras clave: Más allá del 5G; Redes inteligentes; Sistemas de innovación tecnológica.

1. Introduction

Smart Grids have been constantly evolving, especially in Beyond 5G networks. The discussion is mainly about an intersection between data processing and energy consumption. The problems are energy dilemmas generated by 5G and 6G networks. These systems drastically upgrade the consumption energy curve, which smart grids can solve in a vehicular fog proposition. This article leverages the presented problem of energy consumption by the Cloud, which has created a harsh energy curve due to the high data volume of 5G networks. Thus, this article proposes a conceptual discussion about green transition from a digitization perspective. It is necessary for a theoretical scenario since Technological Innovation Systems might result in an appropriate background for understanding the publications, patent productions, and collaboration in this case. As this article will present, Electric Vehicles (EVs) connected with Fog are decisive in fostering beyond 5G Innovation Systems.

The starting point is the following question: How can 5G generate new regulatory standards capable of decentralizing data processing in cloud computing and big data, breaking the sharp energy curve, and generating energy efficiency? The general objective is to investigate publications, patents, and their collaboration to understand the Technological Systems of 5G and Smart Grids in intersection terms. Because of this discussion, some gaps have been found in the literature review.

Table 1 - Discussion Gaps.

Gaps	**Lack of Literature on**
Gap 1	TIS functional studies about publications, patents, and collaboration on 5G and Smart Grids topics forecasting the 5G and Smart Grids' new backdrops
Gap 2	Studies oriented towards decentralized standards in proposals for 3GPP, IEEE, and especially for ITU providing alternatives to data processing by Cloud solutions
Gap 3	Connection between Electric Vehicles (EVs) and Vehicle-to-grid focusing on Fog Computing (V2Fog) as a possible industrial solution to 5G data processing by Cloud problem.
Gap 4	Studies on Smart Grids connecting Beyond 5G from an off-grid perspective, rethinking the perspective of the traditional grid

Source: Authors.

2. Conceptual Proposition

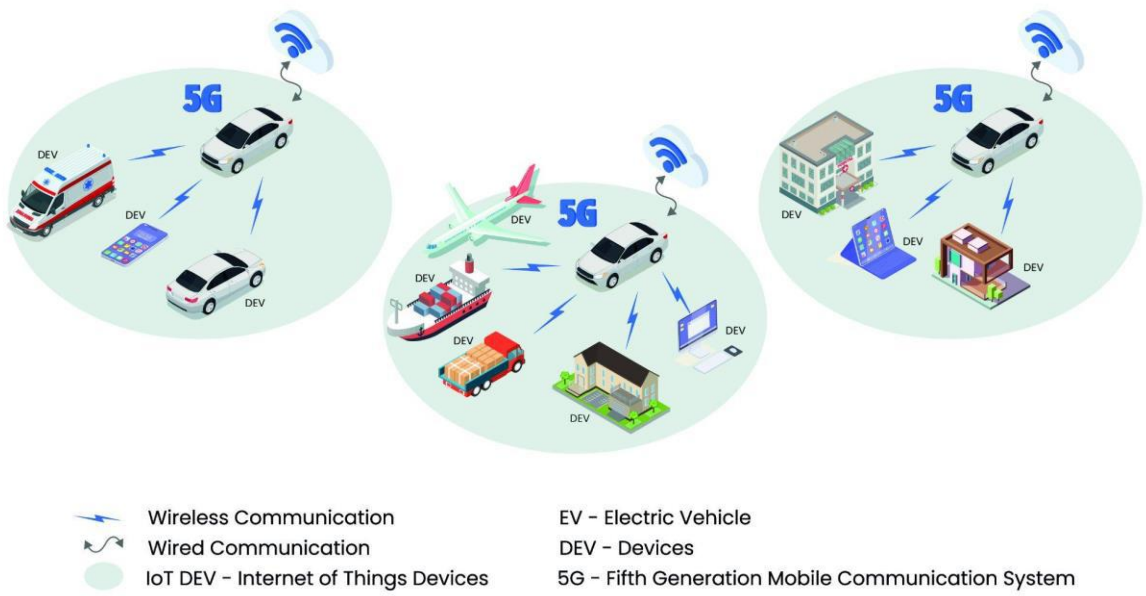
As has been proposed by Li and colleagues (2021), 5G technology has emerged as a relational variable, operating in conjunction with other technologies such as Artificial Intelligence, Big Data, Cloud, Edge Computing, Blockchain, Machine Learning, and the Internet of Things (IoT) (Li et al., 2021; Bourechak et al., 2023; Tskinner, 2019; and Greengard, 2021). Likewise, 5G technology has evolved into an ultra-fast, low-latency, and high-reliability broadband technology (Noor-A-Rahim et al., 2022). The advent of 6G technology can be seen as a direct consequence of 5G, and separating the two becomes increasingly distant. 6G technology aligns with the concept of sub-networks and converging RAN-Core as integral components of the emerging network and architectural paradigms (Chauhan, 2023; Viswanathan & Mogensen, 2020). While 5G technology is more like a revolution of 4G, 6G is seen more as an evolution, as it still depends too much on 5G technology to materialize.

Nevertheless, as said by Li et al. (2021), as a relational variable, 5G just makes sense together with other technological systems, such as healthcare, energy, or agriculture, from an intersection perspective (Bergek, 2002; Jacobsson and Bergek, 2004; Negro et al., 2007; Bergek et al., 2015; Weiss, 2022). Since this premise, this article parts from the Technological Innovation System (Carlsson, 2006; Suurs et al., 2009; Hekkert et al., 2007; Furtado et al., 2020; Kukk et al., 2016; Weiss, 2022; Markard et al., 2015) theoretical background to intertwine two specific sectors: Telecommunication and Energy in the purpose to understand the Smart Grids in Beyond 5G networks. Smart Grids are intelligent electrical energy grid systems that can use these technologies to deliver greater energy efficiency, reliability (through Blockchain uses), and sustainability possibilities (Berghout et al., 2022; Strielkowski et al., 2023).

Applications and services offered over the Internet are referred to as Cloud Computing. The technology and software of data center systems offer these services (centralized platforms that store and organize data). Software as a Service (SaaS) is the name of the service itself. We will refer to Cloud as the hardware and software in the data processing Cloud (Armbrust et al., 2009; Stanoevska-Slabeva, 2010). According to the research conducted by Hassan, Yau, and Wu in 2019, Edge Computing represents a sophisticated computing paradigm that empowers edge servers within compact cloud environments (also known as edge clouds) to expand cloud resources towards the network edge seamlessly. This perspective allows for the execution of computationally intensive tasks and the efficient storage of vast volumes of data directly within user equipment (UEs).

The proposition put forth in this article presents a distinct approach to decentralizing cloud computing. With establishing sub-clouds driven by commercial interests, Edge emerges as the optimal form of decentralized cloud infrastructure. Conversely, Fog Computing represents the evolutionary advancement of Edge in terms of data processing capabilities, making it the ideal choice for the industrial implementation of Smart Grids utilizing Beyond 5G. An extensive review of relevant literature and patents substantiates this assertion. Consequently, we present the following conceptual representation:

Figure 1 - Fog by V2G Perspective.



Source: Authors.

Patents are more impressive, as Vehicle-to-Fog works better in industrial applications than Cloud. Furthermore, scientific publications point in the direction of Fog and Edge. That is considerable, as this article disclosed. Depending on the business interest behind Edge Computing, it is argued that it is the best data processing model. However, Fog is a revolution in data processing, and it has been argued in relation precisely to the technological evolution of this content. Edge has become interested in private networks' commercial proposition, which is also possible.

5G will improve the electrical system, intensifying the energy sector with digital and green possibilities, according to its use in a green transformation perspective. On the contrary, some energetic dilemmas have been discussed in this work from the perspective that these problems will be solved by their own Smart Grid System or in 6G in general. It is crucial to discuss Green Transition from a conceptual perspective, but also qualitatively and quantitatively, to suggest digital transformations and their best consequence, technological change. Technically, it is necessary to have a digital transition, but socially, it is necessary for a transformation to sustainability.

3. Conceptual Foundation

As proposed by Lemstra (2018), there are two qualitative scenarios for 5G development in Europe with implications for policies and regulation. The first is a revolutionary perspective based on the successful 2G deployment, with leadership opportunities on 5G with the business model for 2G in Europe when 3GPP appears safe. The 700 MHz band was available, and the 4G market was fully competitive with the 5G entrance. From its possible perspective, mobile operators have gained importance in the Evolution image as consumers have access to more Bandwidth. Due to the 4G LTE evolution, the 5G appears because of incremental innovations, approbating the 4G LTE background. In developing countries, the image of evolution is commonly prominent, in contrast to the image of revolution with particularities of evolution in developed countries.

From this perspective, Oughton and colleagues (2022) proposed a quantitative scenario approach to demonstrate that the UN Broadband Commission can keep 4G LTE and 5G technology non-standalone (NSA) universally affordable. The authors proposed three module axes for an estimation calculation of universal access: (1) demand forecasting; (2) supply of fibers and required build-out; (3) estimate spectrum costs. In conclusion, the difference among government political choices becomes evident.

Teece (2019, 2022) argued that the global economy is better-connected thanks to wireless technology. The Open Innovation paradigm opened up new possibilities for improving customers' experiences, with new prospects for using devices. The Open RAN and its derivations, from the RAN networks' perspective, have the promise to democratize access. In the same way, the R&D possibilities with Open Innovation brought to the digital economy new markets and new horizons to the "technology markets". 5G technology has, according to Teece (2019), up streamed Innovation with new spillover possibilities.

On the same perspective, Liu and colleagues (2017) demonstrated the encompasses of wireless communication and the possibility of creating and regulating standards since the applications of 5G key technologies engineering as Shen (1999) and Liu et al. (2017) strove to tell the history of China's telecommunications from 3G to 5G, with essential user-focused issues from the Innovation Systems perspective. Developing countries' innovation system, or the technological system, has problems and failures that directly or indirectly affect users and the system itself. Liu et al. (2017) used social and counting sciences to explain how the Chinese 5G innovation system was developed from a historical and econometric perspective with interviews.

Mendonça and colleagues (2022) have a compelling article focusing on knowledge production on 5G technologies and systems issues, with a quantitative approach using VOSviewer software and the Web of Science database. They connected the Innovation Studies with a particular 5G technology vision and analyzed the collaboration in 5G-article production with an engineer looking at the market and regulatory aspects. Their approach is focused on Systems for the techno-economic paradigm for Telecommunications, and these authors see Innovation as a coordinated and participative process to enable the global economy. Besides that, they supervised a machine learning building process to accredit a text-metric analysis.

All this literature proves the robustness of Freeman and Perez's (1988) perspective for economic cycles from Keynes' logic to demonstrate how Innovation works in different perspectives with deterministic economic behavior. The contribution of Freeman and Perez (1988) is translating the logic of the digital and gig economy based on digital platforms and 5G transversely. The combination of 5G technology and its corresponding mechanisms, as argued by Li et al. (2021), alongside Manuel Castells' (1999) confluence perspective on technology, gives rise to a constellation-like manifestation of techno-economic paradigm and institutional change. This amalgamation exhibits a dynamic interplay between evolutionary and revolutionary dynamics, resulting in a transformative and impactful landscape.

Correlated to this, the "neo-Schumpeterian" viewpoint - commonly referred to as "innovation studies" is by nature policy-relevant and empirics-friendly, as proposed by Fagerberg and colleagues (2012). Nevertheless, it is possible to shape some science and technology indicators to forecast policies with oriented missions to make clear decisions (Mazzucato, 2018). After all, the 5G technology backdrop is less than a digital innovation race (Lundvall, 2021) and much more of a so-called learning curve (Lundvall, 2016) in resolutions' gaps of 4G to 5G.

In any case, the digital economy's evolution depends on the disposition of the actors, which is an interactive dynamic disposition inside firms and organizations. This overview result reflects on the industrial process of digitalization and the neo-Schumpeterian dynamic of capitalism (Nelson et al., 2018), which is stimulated by the digitization process, enough with the 5G technology's access to the market and society. The impacts on society will be discussed in the next item.

The linkages among technologies, economy, and ecology from a perspective of accomplishing environmentally sustainable development are significant (Kemp & Soete, 1992). They flow from an evolutionary perspective (Geels, 2002; Schot & Geels, 2008; Verbong & Lorbach, 2012), in which technological change is a non-linear and complex problem disclosed in green technologies. According to Kemp and Soete (1992), the barriers to this proposal are more institutional than economic and social. It must be done with a specific focus on policies designed by all societies.

In contrast, Smith and colleagues (2010) put forth a discourse addressing environmental degradation within the context of industrial development, emphasizing the pursuit of greener Innovation. Consequently, a comprehensive multi-level perspective on socio-technical transitions (MLP) emerges, presenting a framework capable of analyzing the broader contextualization of Innovation within entire production and consumption systems (Grin et al., 2010).

However, integrating case studies into a profound theoretical discussion has raised concerns regarding the introduction and critical assessment of MLP. Both approaches are indispensable to the ongoing debate. Therefore, it becomes imperative for Geels to undertake an in-depth examination that elucidates the theoretical potential of comprehending the actual interconnections between different levels of a complex society with systemic technological systems.

As Kemp and Soete (1992) proposed, the challenge of discussing "friendly-environmental policies" is necessary to comprehend technological change. These policies should be much more from a bottom-up perspective than from a top-down perspective (Goldemberg, 2000). It is necessary for the formulation of an international technological ecology agenda.

The Kyoto Protocol has adopted the Renewable Portfolio Standards (RPS). An RPS initiative is a bottom-up approach at both regional and national levels that can be applied by Member States to remove market barriers for renewable energies, ensuring its continued participation in a competitive environment after restructuring the electricity generation sector. This bottom-up initiative is crucial for a participatory approach to a co-design Policies viewpoint with all civil instances of societal participation (Page et al., 2016; Moser, 2016).

On the other hand, the Anthropocene era, with human action in geological performances, has greatly accelerated the human-environment relationship and the global earth temperature. This has been discussed in many working groups, such as the Conferences of Parts (COP, UN) and the 2005 Dahlem Conference (Hibbard et al., 2010; Steffen et al., 2015).

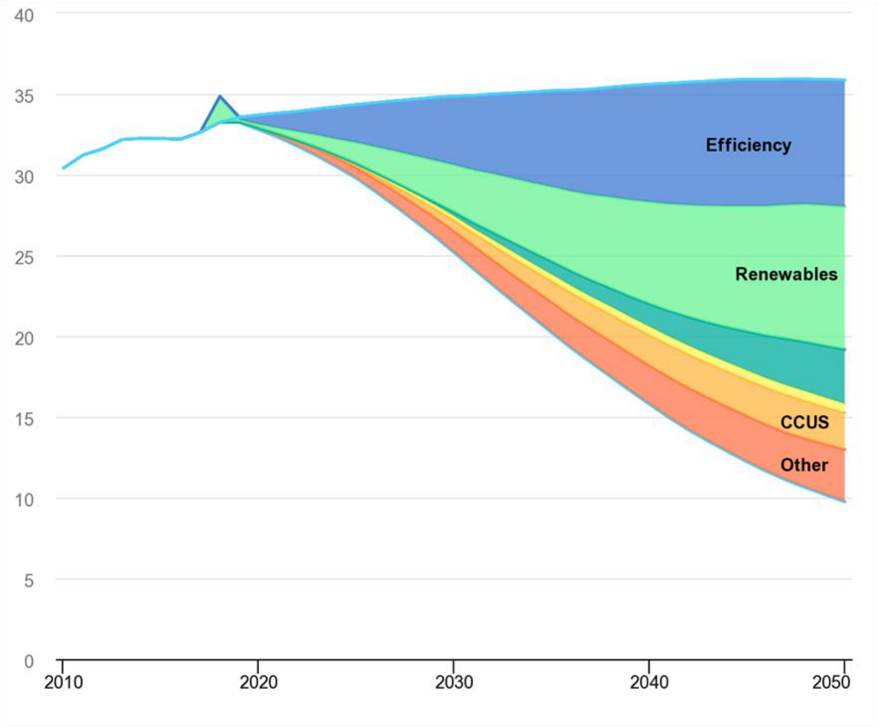
According to Ferreira and Martinelli (2016), mitigation of the problem or adaptation to the effects of changes in the climate system is associated with climate change policy responses. Mitigation measures include replacing fossil fuel sources with biofuels, energy consumption from renewable sources, carbon markets, changes in consumer patterns, waste elimination, and energy efficiency to support reducing and stabilizing greenhouse gas emissions from the traditional model of transports. Brazil and China are similar case studies because they are bigger developing countries with similar pollution emissions. However, there are differences in how to deal with these emissions in political terms (Ferreira & Martinelli, 2016).

In the same way, but in other terms, Rivalles et al. (2022) argue that a climate change phenomenon originated in population growth and its subsequent energy demand. According to these authors (2022), it is necessary to rethink the traditional forms of energy distribution towards renewable energies and sustainable resources in technological terms. Therefore, Fonseca and Santiago (2020) indicate a research orientation towards emerging technologies, such as 5G and 6G. Regarding this, Dias (2021) analyzes smart grids from the sustainable development perspective, as the present investigation has done, but in connection with Beyond 5G.

This way, it is necessary for the economic innovation viewpoint for climate change to be an alliance between private and public actors and investors in R&D on alternative-energy technologies with the participation of all actors (Mowery et al., 2010). At the same time, it is also crucial to a transformative innovation policy, an economic and technological policies agenda focused on mission-oriented policies with a clear direction: targetable, measurable, and time-bound with a practical approach (Mazzucato, 2018). It is an international agenda for technology, economy, and ecology globally, but also in a regional and local perspective, which needs to be correlated in a precise viewpoint since Geels (2002), Schot, and Geels (2008) until a forecasting initiative to an international eco-technology agenda.

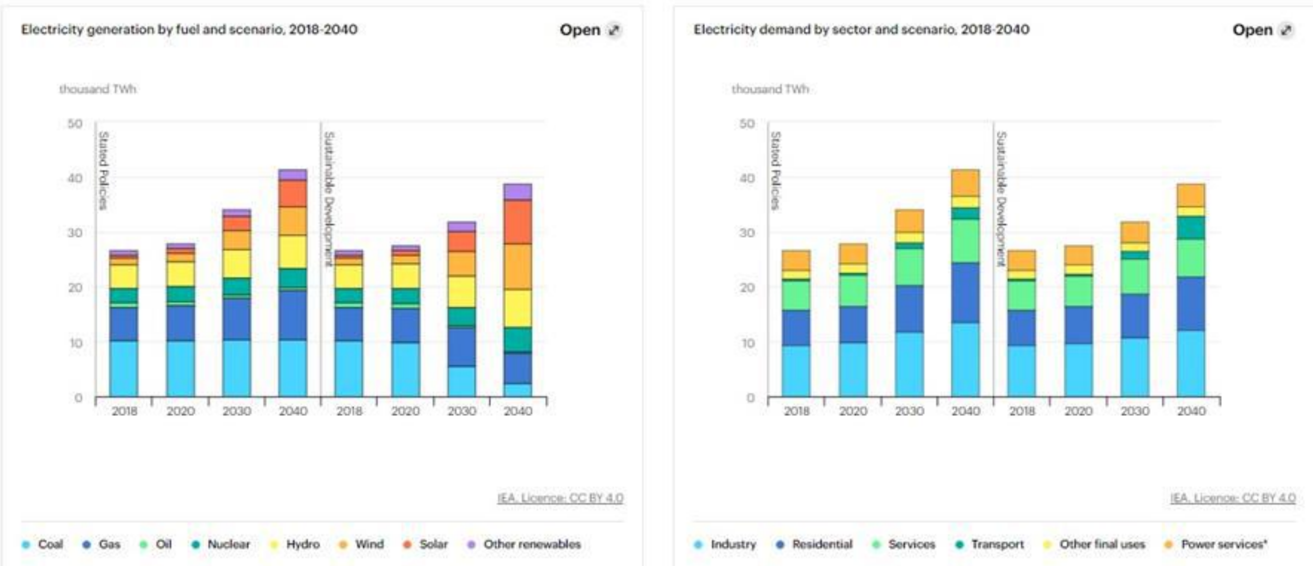
As per the findings of the IPCC Report (2023), the historical and current global trends of greenhouse gas emissions have been disproportionately influenced by unsustainable energy utilization, lifestyles, consumption patterns, and production practices; those factors exhibit significant disparities across regions, countries, and even among individuals. Furthermore, renewable energy adoption emerges as a viable solution. The following figures illustrate the projected global growth of renewable energy adoption until 2050.

Figure 2 - Reduction of CO2 Emissions through Measures in the Stated Policy Scenario as Compared to the Sustainable Development Scenario, 2010-2050 (Global Energy Review 2021 – Analysis - IEA, 2021).



Source: Authors.

Figure 3 - Fuel used to generate electricity and scenario, 2018 to 2040 (Global Energy Review 2021 – Analysis - IEA, 2021).



Source: Authors.

Figure 3 provides insightful data highlighting the anticipated rise in electricity demand, driven by increased household incomes, electrification of transportation and heating, and the growing demand for digitally connected devices. This upward trajectory in electricity consumption significantly affected the record-high global CO2 emissions in the power sector 2018. However, it is crucial to acknowledge that the availability of various low-emissions generation technologies positions electricity as a crucial focal point in our collective efforts to combat pollution and address climate change.

Furthermore, the potential of decarbonized energy sources to significantly reduce CO2 emissions across industries that rely on electricity-based fuels, including hydrogen and synthetic liquid fuels, cannot be overstated. The widespread adoption of renewable energy solutions holds the key to achieving universal access to electricity. In this context, the article suggests harnessing renewable energy, particularly solar energy, as the most optimal form of Vehicular Fog in Smart Grids. This approach leverages the application of 5G technology to power electric vehicles energetically.

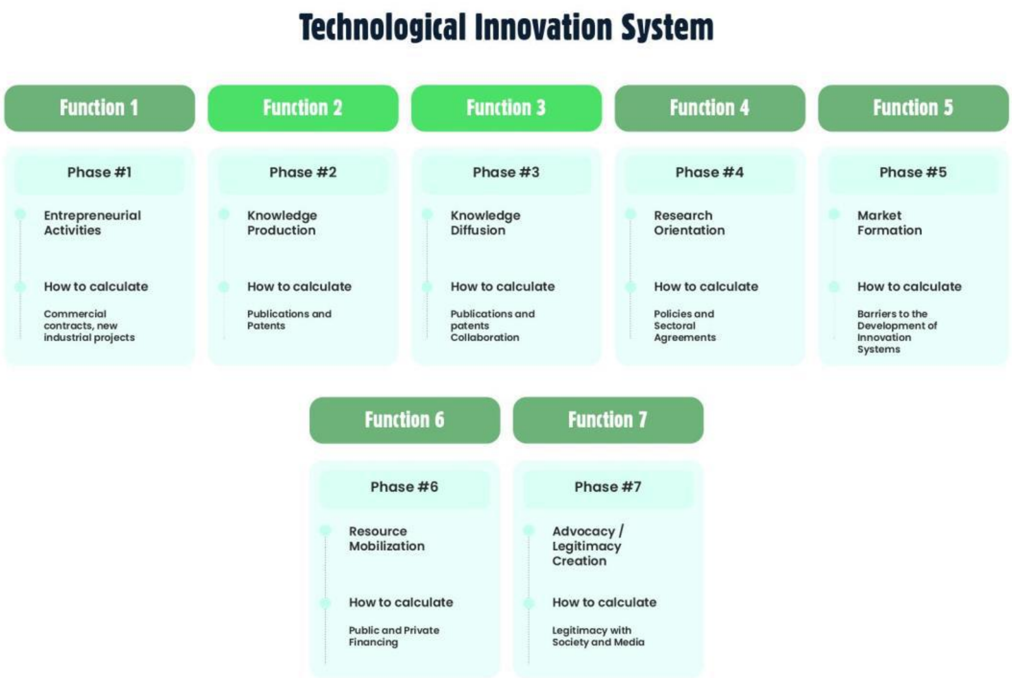
4. Methods

Technological Innovation System (TIS) (Suurs et al., 2009; Hekkert et al., 2007; Kukk, 2016; Furtado et al., 2020; Weiss, 2022; Markard et al., 2015) has been accepted as the configuration of actors, institutions, and technologies are capable of driving the intensity and the direction of Innovation. Thus, Innovation has been assimilated as a singular socio-technical conjunction due to technological infrastructure issues seen here as critical infrastructure, physical, virtual, or digital (Kurtz et al., 2022).

Furthermore, it is worth mentioning that, for TIS approach, Innovation is an interactive process stimulated through the functional performance of multiple actors, with introducing technology premise in the market through the consolidation of its system within a specific context (Furtado et al., 2020; Suurs et al., 2009; Hekkert et al., 2007; Jacobsson & Johnson, 2000; Carlsson et al., 2002; Markard, 2020; Weiss, 2022).

In addition, according to this background, interactions occur between public and private actors - such as universities, research institutions, State, development agencies, and industries in favor of the diffusion of technologies such as 5G and Smart Grids – and also their consolidation in society in general (Bergek et al., 2015; Weiss, 2022). Overall, there are seven TIS functions (e.g., Planko et al., 2017), and this article will analyze two primary functions: knowledge production (F2) and diffusion (F3), as seen in the figure below.

Figure 4 - TIS Functions (See on Hekkert et al., 2007; Suurs et al., 2009; Furtado et al., 2020; Jansen et al., 2011).



Source: Authors.

Besides that, the TIS conceptual background has evolved since Bergek and colleagues (2008), with context patterns that propose new horizons to this perspective because they integrate technological systems into some socio-technical elements and interact with them (Bergek et al., 2008; Furtado et al., 2020; Borges et al., 2023; Bulah et al., 2023; Norouzi et al., 2023; Zou et al., 2023; Martin et al., 2023; De Oliveira, 2022).

Regarding an intersectional perspective (Bergek, 2002; Jacobsson and Bergek, 2011; Negro et al., 2007; Bergek et al., 2015; Weiss, 2022), the analysis of Transition Innovation Systems (TIS) has placed significant emphasis on two consecutive functional components: (F2) knowledge development and (F3) knowledge diffusion (Laes, Pieter Valkering, and Yves De Weerdt, 2019) within the domains of 5G and Smart Grids TIS sectors, which hold pivotal importance in addressing technological requirements. In light of the matter, the electric vehicle, specifically its vehicle-to-grid potential, emerges as a viable industrial application. The operational functions of this paper have predominantly revolved around F1 and F2, as demonstrated in Figure 4.

This article worked with Function 2 and Function 3. Therefore, knowledge production and diffusion give us some elements of entrepreneur activities beyond 5G and Smart Grids, resource orientation, and market formation around the innovation actors, publications, and patent authors. According to this TIS framework background, 5G technology TIS is understood in interaction with Smart Grids TIS to encompass the dynamics of innovation from the actors of both network systems. The 5G Innovation System will leverage Smart Grids TIS, bringing innovations and reconfiguring the global Technological Innovation System. The groundbreaking technologies composing the global TIS are mostly small technologies that direct and reflect the evolution of the technological system.

4.1 Conceptualizing Publications, Patents and Networks

4.1.1 Conceptualizing Publications

Bibliometrics maps out publications and patents and aids in establishing networks within the publications and patents domains, enabling in-depth analyses of TIS functions 2 and 3. The VOSviewer software (Nees et al., 2022) facilitates the establishment of collaboration networks between articles and patents in suitable patterns. VOSviewer is a user-friendly tool that offers several benefits. It is freely accessible online and generates static maps of publications based on their impact factors through its official website, which is favorable for scientific publications. These maps, crucial in publications like the one presented here, provide network visualization, overlay visualization, and density visualization features (Nees et al., 2022).

This article deliberately has chosen the Scopus database for its exceptional qualities. Scopus is widely recognized for its comprehensive and reliable coverage of scholarly literature across diverse research fields. Its extensive collection of indexed journals, conference proceedings, and patents forms a robust academic resource base, ensuring the research is firmly grounded on credible and diverse sources. Scopus is a standout choice for its robust search and analysis capabilities. It empowers the research team to conduct thorough bibliometric analyses, track citation patterns, and extract valuable insights from academic publications. The strategic decision to use Scopus as the primary database underscores the commitment to rigor and comprehensiveness in the research methodology, bolstering the article's credibility and the depth of its scholarly contributions (Rutger De Jong & Bus, 2023). Moreover, VantagePoint has leveraged it to generate quantitative and scientific indicators, aligning with suggested data performance metrics.

Drawing from Nees et al. (2024), this research is grounded in interpreting clusters in subject terms, offering insight into the technical aspects of the Technological Innovation System. Consequently, in all cluster interpretations, Smart Grids emerge as a systematically composed and organized component, as proposed in the map.

4.1.2 Conceptualizing Patents and Networks

This article employs the unique capabilities of PATSAT, Orbit Intelligence and Insight for patent analysis and VOSviewer for visualizing collaborative networks. PATSAT, a sophisticated tool, provides deep insights into patent data, enabling comprehensive analysis of patent portfolios, trends, and technological advancements. Similarly, VOSviewer, a powerful tool, unveils an intricate web of collaborations and partnerships, revealing relationships and linkages between various entities in the field.

These tools play a pivotal role in the systematic examination of patent-related information, identification of significant trends, and extraction of valuable knowledge from extensive patent databases. By leveraging PATSAT, along with patent repositories from the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO), the research is fortified with access to vast patent datasets, laying a robust foundation for patent analysis. The integration of PATSTAT's patent analysis capabilities with VOSviewer's collaboration visualization features not only delves into technological aspects but also illuminates human interactions and knowledge dissemination dynamics, providing a comprehensive view of the research landscape. Moreover, this article utilizes Python, a versatile programming language, to enhance the efficiency and effectiveness of the patent analysis process.

4.2 Empirical Case for 5G in Smart Grids Industrial Applications

The methodology employed began with an empirical examination of the technological convergence in Energy, fostering interaction between Smart Grids and 5G Technological Innovation Systems (TIS). Moreover, it forms an integral part of the empirical exploration of the global context. The methodology consistently focuses on Functions 2 and 3, which involve knowledge production within 5G and its dissemination through collaborative networks, forecasting new perspectives for Public Policies (De Oliveira et al., 2022). It may guide studies on Function 5, the market formation.

5. Results and Discussion

5.1 Sample characterization

The orientation of this search employed an equation with the selected keywords in Eq. 1. This research was accomplished in two stages, one related to the results of publications graphics and the other related to the results of patents graphics.

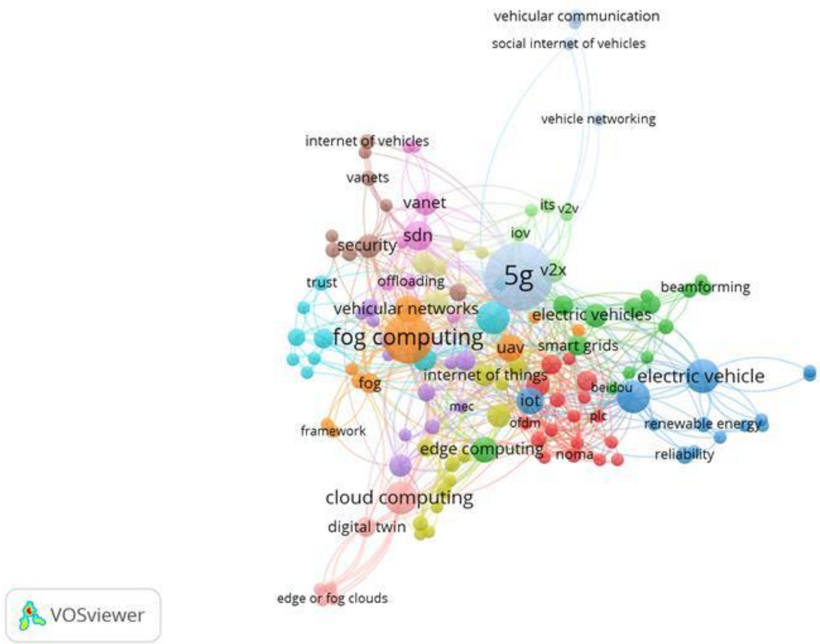
Table 2 - Equation 1 and Equation 2.

PUBLICATIONS (Equation 1) Worldwide 374 papers	TITLE-ABS-KEY (((5g AND technology) OR (5g AND mobile AND communication AND system*) OR (fifth AND generation AND mobile AND communication AND system*) OR (5g AND wireless) OR (5g AND network*)) OR (5g AND beyond) AND (electric AND vehicle*) OR (vehicle AND to AND fog)) AND (EXCLUDE (SUBJAREA , "chem") OR EXCLUDE (SUBJAREA , "medi") OR EXCLUDE (SUBJAREA , "bioc") OR EXCLUDE (SUBJAREA , "eart") OR EXCLUDE (SUBJAREA , "ceng") OR EXCLUDE (SUBJAREA , "agri") OR EXCLUDE (SUBJAREA , "heal"))
PATENTS (Equation 2) Worldwide 147 documents	((5g technology) OR (5g mobile communication system*) OR (fifth generation mobile communication system*) OR (5g wireless) OR (5g network*)) OR (5g beyond) AND (electric vehicle*) OR (vehicle to fog)

Source: Authors.

5.2 Publications

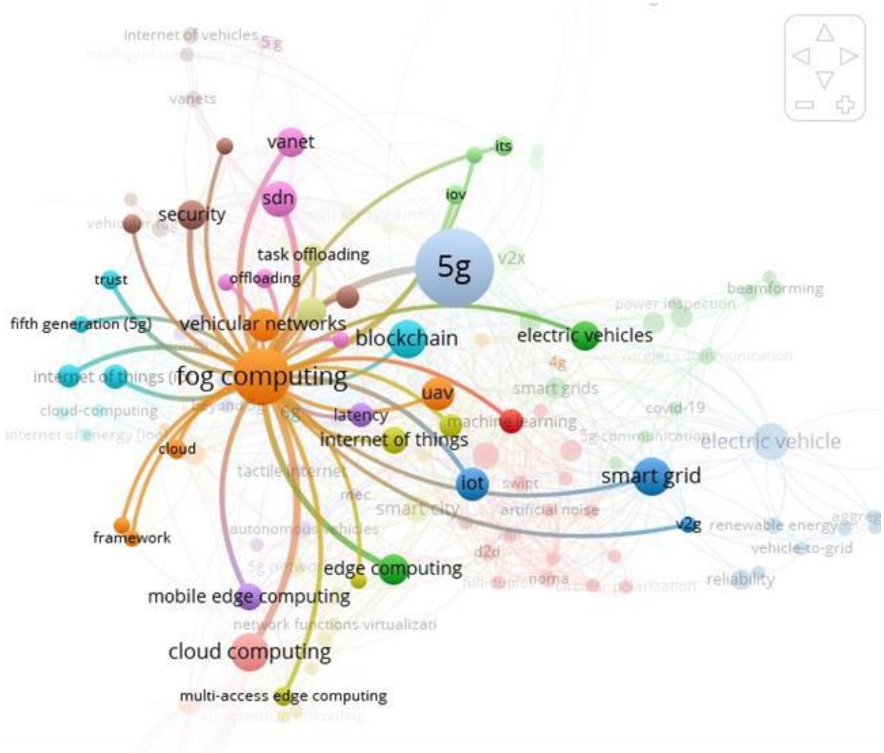
Graphic 1 - Publications worldwide by co-occurrence, authors' keywords with publications' impact factor.



Source: Authors.

This Graphic reveals multiple areas connected with the 5G technology and the Smart Grids subjects. As an interacted figure connecting Telecommunications with Energy sectors, all the clusters connect with a complex and non-linear prism of themes. On the other hand, Fog links with the Vehicular Network, which links to a framework. Fog computing is a framework that depends on the industrial application that is wanted to be revealed. In the green cluster, smart grids link with electric vehicles, beaconing, and edge computing. 5G is linked with V2X, which is a vehicular principle. It is necessary to close in a specific area of interest. Certainly, it is possible to have a good perspective on electric vehicles and fog computing, as shown in the next Graphic.

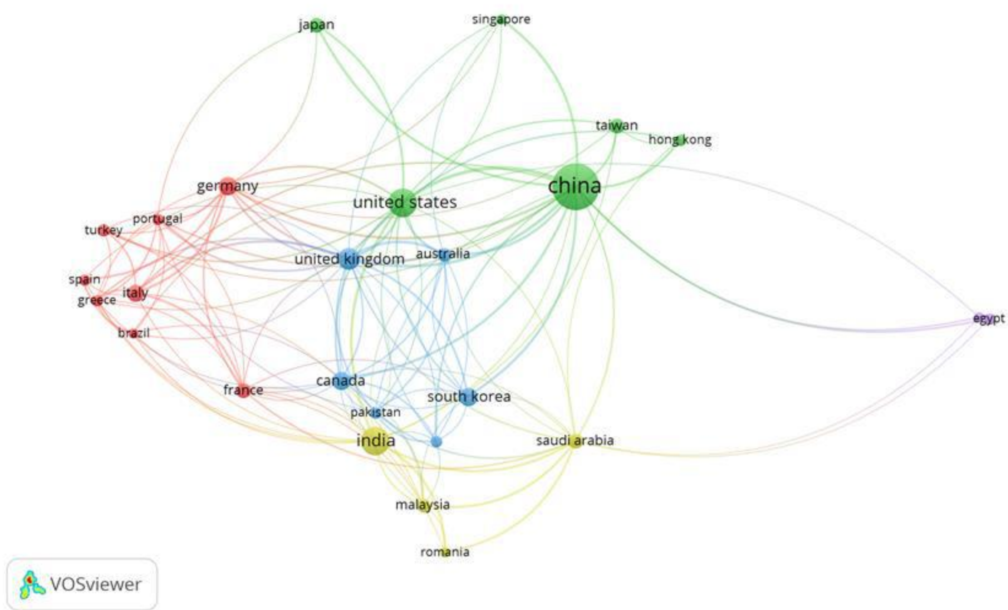
Graphic 2 - Zooming in Fog's Cluster.



Source: Authors.

What is mainly essential is linking 5G and Fog Computing with Vehicular Networks, Electric Vehicles, and Smart Grids in the article's collaboration perspective. It brings perspectives for Beyond 5G paradigms. After all, even if this is not on the map, it will be achieved with learning curves Beyond 5G. After all, the nearest cluster of Fog Computing is vehicular networks.

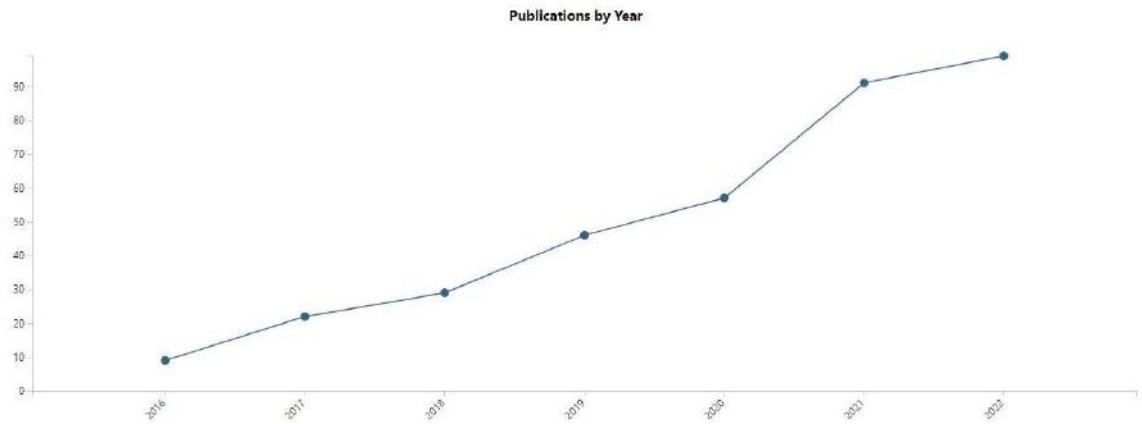
Graphic 3 - Publications by countries.



Source: Authors.

Germany, Portugal, Turkey, Italy, Spain, Greece, Brazil, and France have publications in Journals with the best impact factor, followed by India, Malaysia, Romania, and Saudi Arabia. On the other hand, China, the United States, and the United Kingdom have the most collaborative publications.

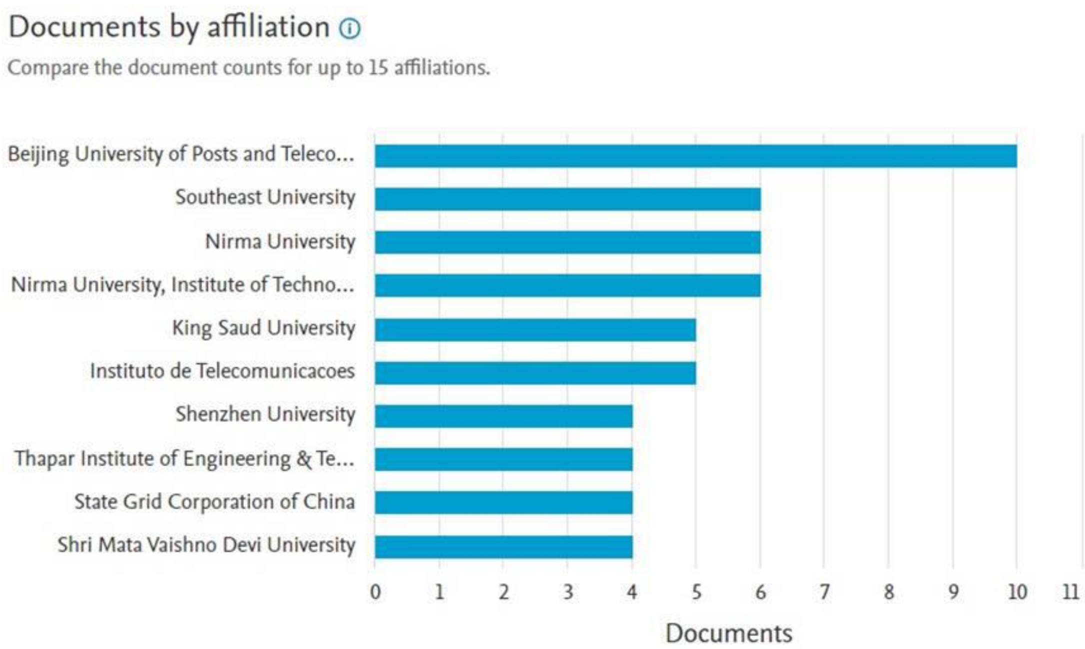
Graphic 4 - Publications by Year.



Source: Authors.

Between 2016 and 2022, it is possible to see an accentuated curve of publication numbers with a graphical representation picked in 2022. This way, the publication curve is accentuated and prosperous.

Graphic 5 - Documents by Institutions.



Source: Authors.

Beijing University of Posts and Telecommunications has the most publications, following the Southeast University, Nirma University and their Institute of Technology, King Saud University, Instituto de Telecomunicações de Aveiro, Shenzhen

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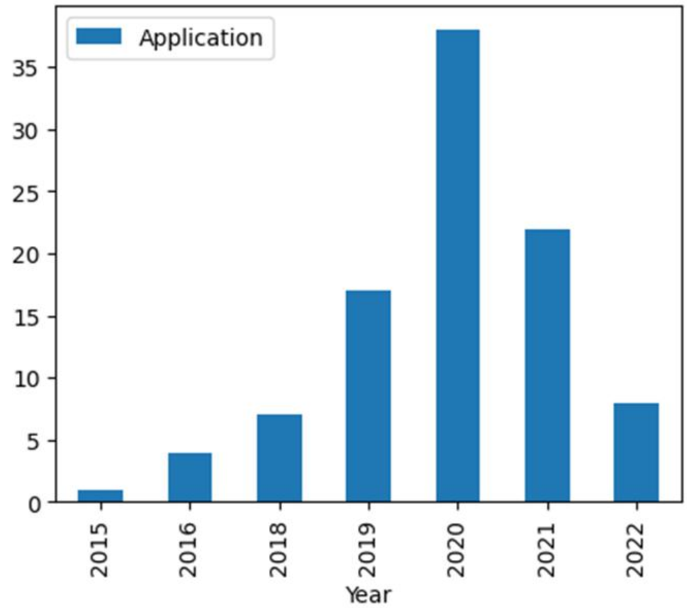
University, Thapar Institute of Engineering and Technology, State Grid Corporation of China, and Shri Mata Vaishno Devi University in India.

5.3 Patents: Graphics and Clusters Collaboration Challenges

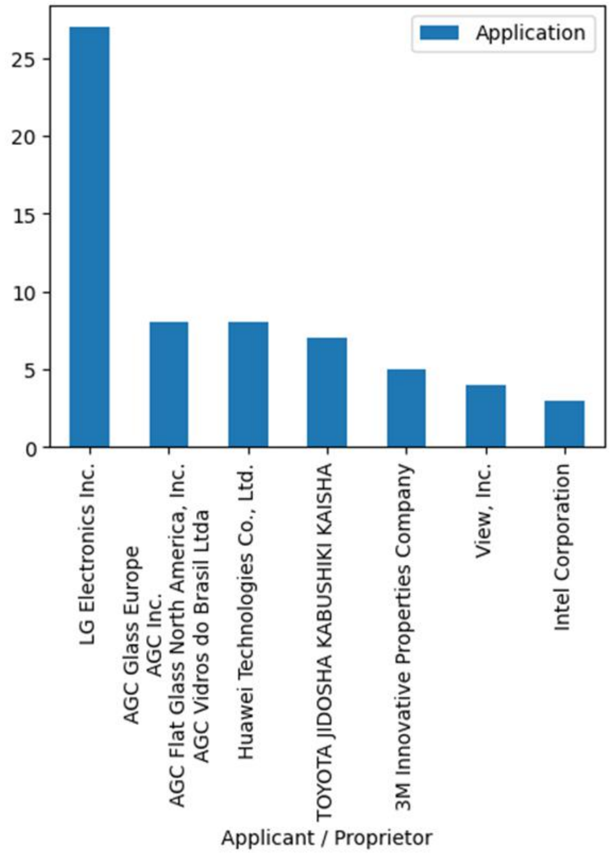
Graphic 6 - Patents by Timeline.



Source: Authors.

2015 is a year before the South Korea Auction. The increase happened in 2016 with this so-called first 5G Auction worldwide. The peak of the graphic is 2020, the year of the North American 5G auction. After these events, there was a decrease in the number of patents around the 5G theme connected with smart grids.

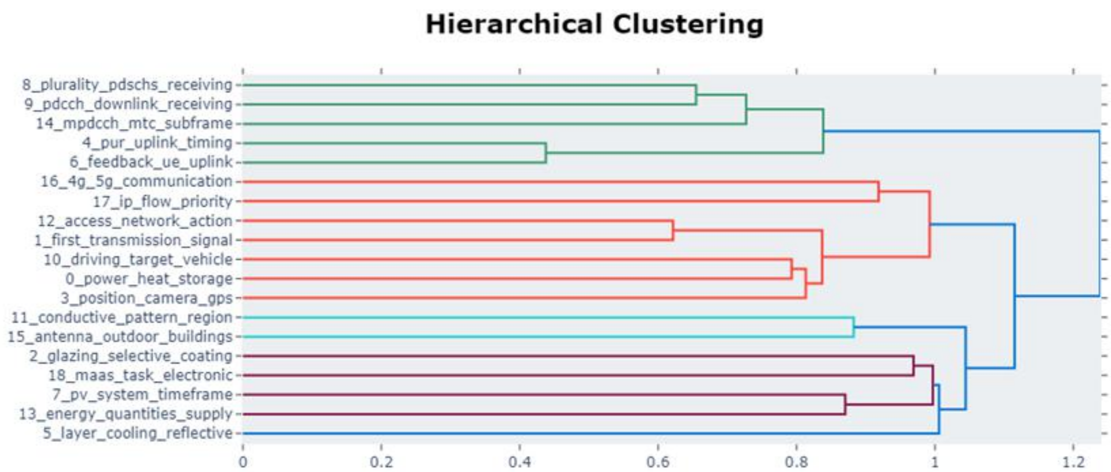
Graphic 7 - Patents by Enterprises.



Source: Authors.

First, we have LG Electronics Company, which holds most of the patents in 5G and smart grids, which use vehicular fog moved by solar energy. AGC Glass Europe, North America, and Brazil come in second place, followed by Huwaei Technologies, 3M, View, and Intel Corporation.

Graphic 8 - Technological Hierarchical Clustering.



Source: Authors.

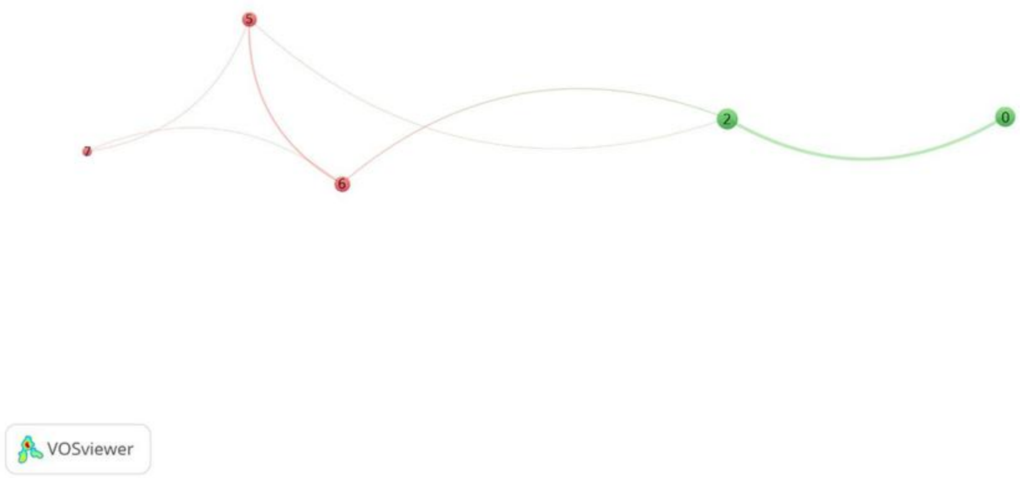
This hierarchical clustering infers 5 clusters on keywords which appear in Graphic 9 on enterprises' patents. Regarding this, the same terms repeat in 5 distinct forms, being able to be correlational in the blue cluster.

Graphic 9 - Technological Overview of Common Terms.

Source: Authors.

Each topic is a conjunction of patent keywords, which compose some clusterization on subjects and selected terms. The 5G and Smart Grids patents universe comprises these keyword maps. The numbering below each cluster is the frequency that each term appears in the patent conjunction.

Graphic 10 - Technological Overview of Patent Collaboration.



Source: Authors.

Each point of the map corresponds to a number in Graphic 9, according to each topic. For example, topics 7, 5, and 6 collaborate in patent terms with 2 and 0, and so on.

5.4 Literature Considerations

Liu and colleagues (2022) have proposed that 5G technology holds the potential to address the issue of high-energy consumption by electric vehicles through the facilitation of collaborative energy commerce. However, reliance on a centralized scheduling system poses performance bottlenecks and needs more adaptability within a distributed network. Furthermore, there exists a need for more transparency in the cutting-edge vehicle-to-vehicle (V2V) power supply. The authors suggest a Blockchain-based collaborative energy trading scheme designed explicitly for 5G-enabled social vehicular networks to tackle these challenges. This scheme utilizes a distributed market mechanism to ensure reliable energy trading without dependence on a centralized dispatch center.

In their research, the authors developed a price matching and trading engine for V2V energy trading using game theory to enhance societal welfare. Blockchain technology maintains a transparent record of energy trading data, while smart contracts enable efficient transaction matching and predictable pricing. Simulation results confirm the efficacy of the proposed scheme in improving social welfare and alleviating network burden. The research objective of this article is to explore the possibilities of the Social Internet of Vehicles (SIoV). Focusing on enhancing energy management to reduce EV energy consumption, which remains a significant challenge in smart grid development and autonomous transportation systems, the authors aim to pave the way for realizing SIoV (Liu et al., 2022a).

Baccarelli and colleagues (2017) have a significant article on the Fog Computing paradigm to create a framework for Fog of Everything, bringing together the Smart Cities principle from a Smart Grid perspective. These authors consider smart devices capable of introducing the most significant volume of data in a heterogeneous environmental transfer based on Fog. On the other hand, according to these authors, it is still impossible to unbind Cloud Computing. It is possible to have an integrative perspective on the Fog-Cloud complementary.

On the other hand, they present a Smart Grid perspective integrated with the Fog paradigm in Internet of Energy (IoE) terms, which brings together the Internet of Everything concept. According to Baccarelli et al. (2017), this Smart Cities discussion steps up open issues about the Internet of Energy based on environmentally suggestive data processing. Keshari and colleagues (2022) proposed a crucial survey on vehicular fog computing (VFC). According to a survey review, these authors proposed some VFC architectures based on sensing, communication, computing, and storage, proposing a mathematical model to support fog computing instances on vehicular possibilities (Baccarelli et al., 2017; Keshari et al., 2022).

Chen and colleagues (2023) have presented a comprehensive review article to facilitate a smooth and efficient transition from fossil fuels to renewable energy sources. Their work provides a meticulous evaluation of the application of smart meters in power grid control and optimization. Within this article, the authors establish a strong correlation between the concepts and strategies of Smart Grids and smart meters in transforming towards renewable energy sources.

By linking Smart Grids and smart meters, Chen et al. (2023) emphasize the importance of focusing on the consumer's energy generation domain. They highlight that smart meters are vital in reducing carbon emissions while expanding power transmission and distribution. The authors propose the implementation of communication interfaces utilizing wireless technologies, such as 5G and 6G networks, as well as incorporating Electric Vehicles (EVs), Cloud Computing, and Smart AI into the system (Chen et al., 2022). These technological advancements are crucial in achieving an effective and sustainable energy transition.

Bourechack and colleagues (2023) have also presented a comprehensive review encompassing various industrial sectors, including Smart Grids, Smart Agriculture, Smart Environment, Smart Healthcare, Smart Industry, Smart Education, Smart Mobility, and Security and Privacy. Their study offers a qualitative comparison emphasizing the confluence of functions and applications of artificial intelligence at the network edge and the crucial supporting technologies for edge analytics. Additionally, the authors explore the significance of integrating Edge Computing and AI into IoT-based applications, proposing potential solutions at various levels of artificial intelligence. Furthermore, they highlight the importance of leveraging 5G intelligent applications through Edge Computing to enhance Smart Services, particularly within Smart Grids (Bourechack et al., 2023).

A significant article by Chafi and colleagues (2022) concludes by highlighting the critical role of Smart networks in harnessing the resources of 5G networks, particularly in the context of the Internet of Things (IoT) applications, such as massive machine-to-machine communications (M2M) or ultra-reliable low-latency communications facilitated by dedicated equipment (D2D). The authors emphasize the distributed utilization of cloud services, which enables Fog and Edge Computing infrastructures and applications to leverage all available resources, including network equipment and connected devices. This comprehensive approach aims to optimize cost, energy, and latency based on predetermined optimization criteria (Chafi et al., 2022).

Therefore, there needs to be more research regarding the interrelationships among EIoT, energy efficiency, and the deployment of 5G networks (Shehab et al., 2022; Ziad et al., 2022). Further investigation is needed to understand how these elements can be effectively integrated to address the challenges of energy consumption and sustainability in future wireless networks.

6. Final Considerations

The literature reviews appointed directions to distributed energy needs, evolving traditional energy sources, and centralized data storage forms with Cloud through Edge and Fog Computing, using Smart Grids as the best solution to the data traffic and the sharp energy curve of 5G use and beyond. Smart Grids within the 5G and 6G context should have a decentralized energy source of data processing, using renewable energy, especially the EVs connected to these sources, like vehicle-to-grid or vehicle-to-fog - the best industrial application to 5G/6G technology in energy problems. The best solution to the energy problem in 5G/6G terms is not Edge use. On the other hand, EV applies to the vehicle-to-grid or its best alternative, the vehicle-to-fog, the most decentralized solution in renewable energy terms.

Regarding the Technological Innovation System, knowledge production and its collaboration remain the vehicle-to-grid and vehicle-to-fog alternatives to 5G technology coupled with the demand for data traffic questioning. TIS Functions 2 and 3 appoint these directions. Renewable energy sources and technologies, possibly their uses, such as Edge, Hybrid, and Fog Computing until vehicle-to-grid and Fog, are forecasting forms to deal with the demand for data traffic. Finally, it is necessary to think of V2G off-grid, which results in V2Fog and vehicle-to-grid systems beyond the traditional power grid systems, using EVs. Since 2022, the World Economic Forum (Schell, 2022) has discussed it.

Addressing the gaps above is imperative to further advance the understanding and implementation of V-Fog systems. Future research should focus on validating and optimizing the proposed structures while emphasizing trust and confidence in the allocation of MVs within vehicles. By addressing these aspects, researchers can contribute to developing robust and efficient V-Fog systems that leverage the benefits of decentralized energy production and virtualization technology.

New regulatory models are essential for data collection processing by Fog Computing to the International Telecommunication Union (ITU), 3rd Generation Partnership Project (3GPP), and the Institute of Electrical and Electronics Engineers (IEEE) at a transactional level until 2030. Smart Grids could be based on new data processing parameters. In the same way, public policy developers in both the telecommunications and energy sectors must focus on encouraging green technologies and renewable energies in a decentralized generation. The data processing collected by Cloud and Big Data could be decentralized by the EVs dynamic, using renewable energy as parameters of green transportation and energy resources.

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