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RESEARCH TRENDS IN HOUSEHOLD ENERGY MANAGEMENT SYSTEMS: A BIBLIOMETRIC REVIEW*

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Abstract

World energy demand is constantly growing and inevitably entails the need to optimize processes for their best use. It is therefore necessary to identify the set of solutions that the scientific literature proposes on this topic, that's the reason why this article shows the results obtained from the application of a bibliometric analysis in the identification of research trends in relation to energy management systems in homes. Through the application of search equations in the Scopus database, the most published topics, the most cited articles and the authors' networks are found in order to identify emerging perspectives on the subject. As conclusion, the emerging themes with the greatest impact in the academic field and their practical implications in society and energy management are developed.

Keywords: bibliometric analysis, energy management systems, household, research trends

1. Introduction

Home energy management systems represent a dynamic way to use energy intelligently, optimizing the performances of process-aligned systems (such as environmental care) based on minimizing impacts such as costs that are based on innovation strategies by integrating performance-ranked procedures and installation capabilities, so, include a properly structured design algorithm makes environments adapt to new changes from management and organization. In this same line, (McIlvennie et al., 2020) suggests that smart technologies in homes represent an opportunity to change the way new models are structured that are based on science and research, furthermore, emphasizes the importance of

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systematizing households as it represents the future according to the energy impulses and impacts that are made in the use of new and improved systems.

In this same context, home energy systems focus on sorting tasks to ideally distribute circuit control and response to user requests, highlighting among other things, the response time of control systems revealing optimal results in intelligent energy systems. On the other hand, Japan is one of the pioneer countries in the development of this technology providing users with energy-saving opportunities, installation facilities and promising schemes for community development by exponentially integrating projects that impact citizens' lives, Additionally, present research that highlights self-sufficiency in technical considerations such as simultaneous electricity and heat loads highlighting the performance and improvement of services in the performance of new and improved technologies (Li et al., 2020).

In this sense, there are investigations in favor of improving the quality of life of people in their homes and reducing the heat loads that people are exposed to in microclimates with lighting conditions, humidity in the air, changes in ventilation and emission of harmful substances within your home or job, therefore, seeks to create a healthy microclimate within domestic facilities that provide comfort of life, protection and energy efficiency, according to (Aloi et al., 2019), to counteract the problems energy, consumption, microclimate and presence of pollutants that compromise people's health, it is necessary to implement a technology of controlled mechanical ventilation. Likewise, other studies propose for the same situation to implement ventilation and thermal control modes with PVC windows of greater tightness with the support of software (Kovalnogov and Chamchiyan, 2016).

On the other hand, energy technology stands out more and more in the world, from new systems that are applied in all contexts at the industrial and residential level, and this is not too much to highlight the important advancement that is made in energy applications from photovoltaic developments that are nothing more than clustered cells in a battery bank that provides loads to intelligently power electrical systems. In addition, the clean way in which energy is concentrated in systems, is the sun. In Italy for example, the obligation to construct buildings with “almost zero energy” was established for the year 2019. The photovoltaic system is a key element to achieve this, since by means of panels it makes the biostructures more sustainable and therefore achieves energy self-sufficiency and are in harmony with the environment (Martelli et al., 2019; Matuska et al., 2019). This is reinforced in Dao's research where it exposes the need to integrate solar panels into smart electrical systems providing the possibility of benefiting not only users, but also, to the environment. In this sense, this method reduces active energy which may cause economic losses in households but investment in the medium term is recovered by the integration of this technology.

Another aspect to highlight in this research is the integrated programming that energy systems implemented in homes have, that is, the construction of algorithms that interact in a practical way with domestic systems allowing users to overcome obstacles to demands in the acquisition of innovation projects, In addition, operating periods are intricate in product simulations that highlight the use of new tools for the benefit of developments for better model management in high-impact energy projects (Merdanoğlu et al., 2020).

Energy systems demonstrate a strong trend in the implementation of projects that connect current technologies in industrial contexts, transport developments, the connection of digital systems monitoring environmental, residential and personal environments. In addition, applicability in agriculture, aviation and everything that relates the use of energies, implying that technologies have evolved to the point of significantly changing the way they develop products that reduce electrical loads with user comfort and control of systems digitally. The new technologies are included which has allowed to evolve and improve certain behaviors at the end-user level.

As a result, consumers of these technologies report critical information about the systems in order to substantially improve services, highlighting the constant research that is

being carried out against the energy developments implemented in the households, thus creating the methodology of regulating the tools so that they do not present monitoring failures, overloads and insecurity on the part of end users. One of the advantages that these types of systems have is the structure with which the ways of implementing energy technology are developed, one of them is the hierarchical analysis where the main preeminence is the maximization of profits and the reduction of peaks in the network in an upward way, so that structural designs allow to partially integrate many residences that adopt this technology , on the other hand, the biggest disadvantage of this system is the high cost and the inability for many users to access (Gholinejad et al., 2020).

Finally, residential technology in the use of control and automation of the electricity grid represents for an end user reliability, network balances, security, resource management, device optimization, medium savings and lakes term but a disadvantage in the initial cost, so research tends to have a strategic bidirectionality to consistently access the current applications of the digital world in the development of office domotic projects and domotic generation in the verification of energy contexts that benefit not only the end user, but also the economy of the regions or countries and the positive impact on the environment (Nizami et al., 2020).

The topics presented above, being supported from their level of importance at the bibliometric level, allow us to identify academic bases that support the development of research projects that significantly impact the life quality of people. Through bibliometrics, a tracing of indicators is carried out that will allow reinterpreting the dynamics of scientific production within the framework of analysis topics so that those who are interested in advancing solutions in this field of knowledge have a prior reference for existing production, either to contribute with new knowledge or with the aim of applying some previously defined concept in a specific situation (de Oliveira Neto et al., 2019).

The main objective of this study is to analyze the research trends in household energy management system using bibliometric analysis in order to identify emerging technologies that contribute to the exponential development of this important topic.

This work is divided in three main parts:

- applying a search equation to the Scopus database;
- Identification of the impact of publications by journals, authors and networks of the most cited authors;
- Discussion of thematic trends and conclusions.

2. Material and methods

The proposed methodology is a bibliometric study based on the formulation of a search equation in the Scopus database. To find trends in scientific production on the subject, has been started with the key terms: energy management system*, home*, residential, manage and fireside). The SCOPUS database has been selected, as it is a tool that allows for large-scale information analysis as it is a multidisciplinary repository of abstracts and citations in scientific research.

From these terms, the search equation was constructed with the key terms and the Boolean OR/AND operators, for the exclusion and inclusion of the search, considering the objective of the investigation; the equation used is presented below:

(TITLE ("energy management system*") AND
TITLE (home* OR house OR residential OR manage OR fireside))

The search in the database for the period 1979 to 2019, returned 492 results of published articles, presenting indicators of quantity, quality and structure. According to the findings, information associated with the publications was highlighted as quantity indicators: main journals, productivity of authors, institutions, and countries; likewise, quality indicators

appear, measuring the impact of citations by author, magazine and year; as well as structure evaluating connectivity between publications, authors and related areas of knowledge.

3. Results and discussion

3.1. Measuring impact by journals

Compared to the most cited journals, the results of this research indicate that 0.6% of the journals account for 25% of citations in the field of research, 9.1% of these reaching 75% of citations and 12.9% achieved 80% of appointments. Similarly, the production index shows that 5.5 of journals (1.6%) have 50% of the citations in the field, while the transient index is 72.72, where the journals (22.6 %) have no associated citations in the topic. Fig. 1 presents the results.

IEEE Transactions on Smart Grid journal has 1,386 mentions in publications associated with the research field, showing the high impact it has, this international interdisciplinary journal is focused on computer science, with publications of development research and theories of principles of smart grid technologies and systems, based on the generation, transmission, distribution and delivery of energy. With 326 associated citations, his most impactful published work is "An optimal power scheduling method for demand response in home energy management system", where a programming method for the effective use of energy management systems in a network is proposed of domestic area, with which it is achieved that all household appliances operate profitably, guaranteeing stability throughout the electrical system (Zhao et al., 2013). The rest of the journals with the greatest impact on the dissemination of knowledge in the field of research have fewer than 500 citations.

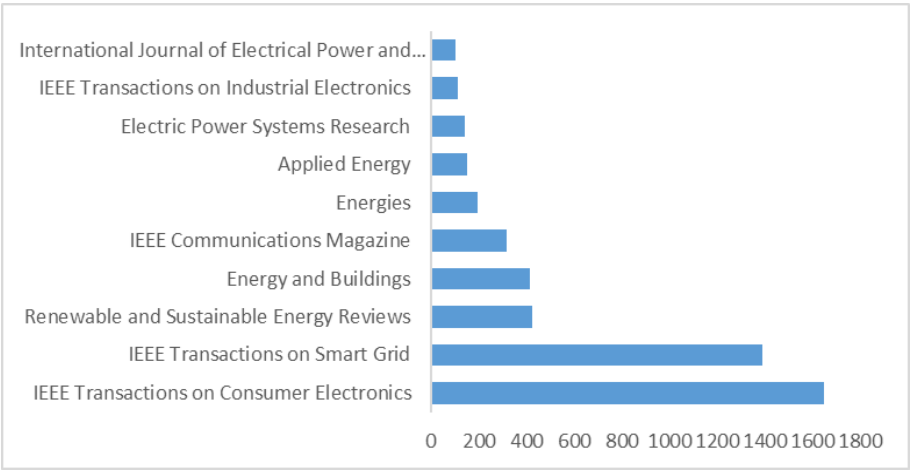

Fig. 1. Most cited journals

3.2. Impact identification by author

This indicator shows the quality of authors in the field of interest, given the number of citations each of them has in their research work. In Fig. 2, we find the 10 authors who have the greatest impact given the mentions of each one. The first two authors at the top of the list are Han DM and Lim JH, who have two publications in the field of interest, where they publish the design and implementation of intelligent systems for the administration of energy in the home based on different communication technologies. wireless, which provide greater control of household devices (Han and Lim, 2010a, 2010b).

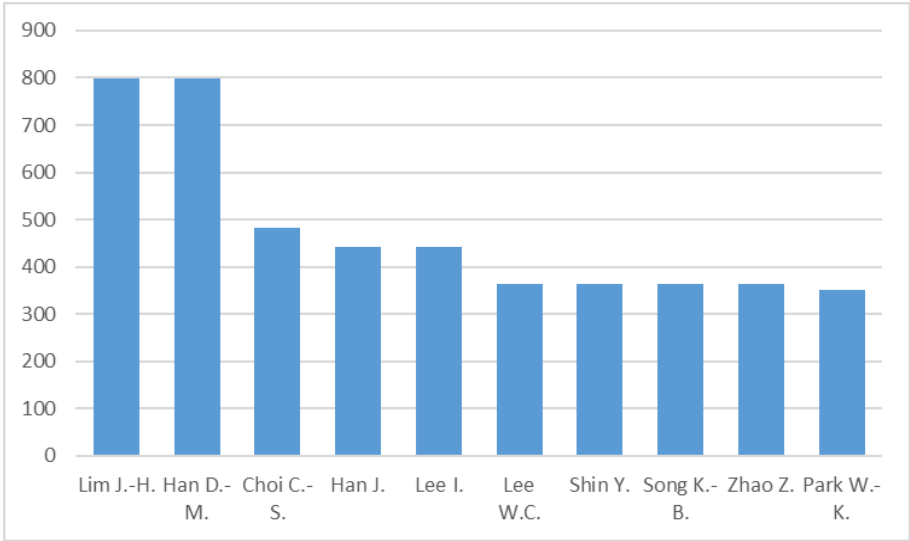

Fig. 2. Most cited authors.

3.3. Most cited authors network

In Fig. 3, it is possible to see the collaboration and co-authorship networks existing among the authors that have a higher level of impact on the energy management systems in homes topic, showing that there are 5 networks made up of 24 authors in total and each of them has 200 or more references associated with it. Starting with the smallest networks, there is a network composed of the authors Kumar S., Lee G. and Ozturk Y., with 225 citations, they carried out research to propose personalized energy management systems that respond to the demands in homes, it consists of programming and controlling household appliances by recommending optimal hours for their use, based on the lifestyle of the people that lives in there, which allows saving energy (Ozturk et al., 2013). These authors seek to respond to the responsibility of citizens to go green, suggest an architecture for the sensor network for the devices and offer some results on the use of a neural network controller, which manages to predict the use of these devices, being the starting point for developing this type of system (Senthilkumar et al., 2010).

The following authors network is formed by Niyato D., Xiao L. and Wang P., they have a publication in the field of research that accounts for 279 citations, where they identify the role of machine-to-machine communication technology in smart grids, the shortcomings of this design for a domestic energy management system are also identified, concluding in the same way with an optimal programming that helps reduce costs thanks to the prior identification of domestic demand (Niyato et al., 2011).

The following two networks are made up of a major number of authors with greater impact, in first place there are the authors Choi C.-S., Park W.-K., Han J.-S., Lee I.-W. and Kim S.-H., who present studies on the creation and implementation of intelligent energy and renewable energy management systems based mainly on Zigbee technologies, whose functionality is provided by a set of high-level wireless communication protocols for use with low consumption digital broadcasting as well as PLC technologies, the programmable logic control that communicates as a network to the Zigbee to monitor power generation, all in order to optimize the use of energy (Han et al., 2014). And finally, the authors' network Zhou B., Li W., Chan K.W., Cao Y., Kuang Y., Liu X., Wang X., Lim J.-H. and Han D.-M., who also carry out research on intelligent systems for energy management in homes, through

technologies such as IEEE 802.15.4 and zigbee (Han and Lim, 2010a), microgrid technologies (Liu et al., 2017), smart algorithms (Liu et al., 2019) and simulators for this energy management at home (Sun et al., 2019). (Zhou et al., 2016) presents that all this is due to technological advances in bidirectional communication, information, measurement, energy storage systems and smart grids. This last network has more than 1000 associated citations, which shows the great impact of its publications.

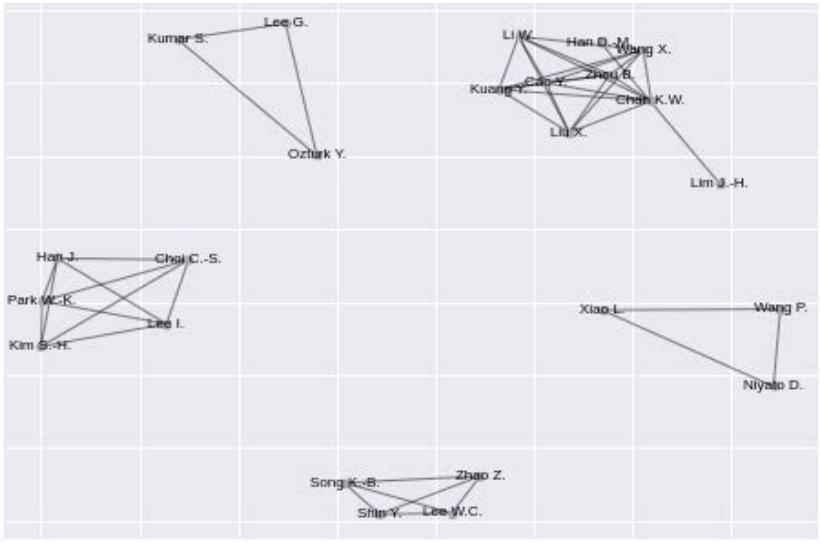

Fig. 3. Most cited authors network. Source: own elaboration form Scopus data

3.4. Discussion about topic trends

In this section, an analysis about topics or keywords with more publications and its conceptual treatment is presented in different viewpoints in order to understand the approximations taken in account in the scientific community. Fig. 4 shows this relation in the time lapse from 2014 to 2019.

3.4.1. Automation

Process automation not only improves system performance, but also provides security in the use of systems, so adoption patterns significantly improve with the reliability of systems in relation to linear programming in energy systems, in addition, they have protections that prevent the violation of electrical standards protecting the systems implemented in residences at the operational level (Dao et al., 2020), in the same sense, automation reflects a wide use of the Internet as a communication channel being also considered an enemy because of the demand for data that is available and the vulnerability of online codes, but it is undoubtedly the most powerful tool in terms of monitoring in relation to long distances (Zhang et al., 2020).

Automatic systems allow you to control and take action when necessary, taking into account that they are exact in the programming of electronic devices, thus reducing energy consumption. In a study (Suherman et al., 2019), it shows that the design and evaluation of an extension device for a remote control of an air conditioner minimizes energy consumption on average by 32.3%.

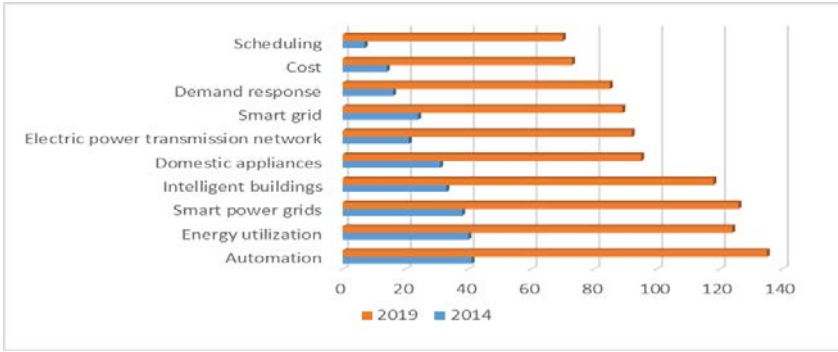

Fig. 4. Keywords trends from 2014 to 2019

On the other hand, electrical systems report high reliability in consumption indexes through automated platforms that manage the energy consumption of smart homes, in this sense, and from automation high quality services must be generated that operate on data acquisition, error detection and above all disturbances demonstrating that algorithms previously installed on equipment such as Power Line Controllers (PLCs) offer accuracy and moderately possible costs for consumers who demand properly automated smart networks (Rodrigues Junior et al., 2020).

3.4.2. Energy utilization

Since smart grids were part of the technological contexts consumers decided to intelligently manage homes, using knitted technologies and generating a high peak of reliability where efficiency and development are promoters of this new and improved energy condition, as well as evolution and trends harmoniously incorporate automated systems with simple use by end users , more than, to achieve this goal companies presented goals that would exceed expectations in terms of efficacy and quality (Khan et al., 2019). In terms of energy efficiency, they are evident according to (Nikolaenko et al., 2017) alternatives to increase it with respect to the lighting of spaces, supposes as an example the suspended lamps with a battery that can be charged with a combination of removable solar energy and energy networks, which allows reducing electricity consumption, the use of fuels organic and the amount of harmful emissions to the atmosphere.

As a result, energy management approaches can significantly improve the economy and performance of residential households depending on the technological approach implemented, and this relates directly to the variable time that mathematical techniques predict optimal control models in a home to meet energy consumption intelligently and competently (Yousefi et al., 2019), however, energy use has increased in recent years, so energy systems must intelligently integrate into the daily lives of people and businesses through clear goals with integrated knowledge that respond to autonomously controlled needs (Chouaib et al., 2019).

3.4.3. Smart Power Grid

The increase in the population makes energy consumption considerably increased, where the idea of establishing smart networks capable of supporting intelligent systems that consistently communicate the conditions of a home in real time, so smart networks must be focused on high-level critical situations that not only impact the global economy , but also, the global environment and nothing more critical than using these technologies based on high-level algorithms when the same technology use different concepts to build a new projects (Cao et al., 2019).

In this order of ideas, smart networks seek to design and create prototypes that manage electronic control units for home monitoring with this technology, in addition, to use other types of renewable sources to significantly improve the systems, in addition to this, having supported systems that give the possibility of having alternating sources and backup communication systems (Kgope and Ogudo, 2019). Finally, energy flexibility plays a key role in smart grids, benefiting not only users, but also service providers involving more markets and increasingly with better options (Aguirre Mesa et al., 2017; Sousa et al., 2019).

4. Conclusions

The bibliometric analysis shows that the interest and impact of research on energy management systems in homes has increased, finding that the inclusion of smart technologies has become very important in the operation and results of these systems. These technologies have been implemented with a view to finding the optimal benefit in energy management and control, giving stability to the systems and thus providing users with security, care for the environment and cost reduction, all thanks to its integration with the procedures. The technologies with the greatest impact identified in the investigations of this bibliometric analysis are: Zigbee, PLC, IEEE 802.15.4, microgrid technologies, intelligent algorithms and simulators for this energy management at home, all due to technological advances in bidirectional communication, information, measurement, to energy storage systems and smart grids.

The research trend in energy management systems in homes reveals that the topics related to automation, energy use, smart grids, smart buildings, household appliances, power transmission networks, demand response, costs and planning has increased. Process automation provides security, works as a communication channel and is a monitoring tool for error detection, this automation that is carried out by implementing smart technologies and networks, is responsible for generation, transmission, distribution and delivery energy intelligently, in order to improve the economy, household performance and meet their needs.

Many studies have been focused on the search to create and implement systems that manage energy consumption. Due to the growing demand by households, however, it has been shown that they are expensive, but they will finally obtain better benefits over time and the investment will be pay off. Planning is a key factor for such systems and the inclusion of design algorithms has allowed to evolve and respond to the demands of households, previously identifying their behavior for the design of the necessary system, which ultimately translates into a benefit not only for the user but for the economy of a country and the positive impact on the environment.

The management of energy consumption not only depends on technical approaches, these must be accompanied by aspects oriented towards a better approach to the end customer, identifying aspects of usability and practice in use. In this aspect, the design of the products, as well as the implementation of the specific parameters of energy efficiency and labeling, should focus on a better user experience that is directed according to the social and cultural particularities of the region.

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