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Overview of Energy Management for Smart Buildings: An Opportunity for Engineers in Peru

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Abstract This article is important for professionals related to the world of infrastructure and building, because it provides what is necessary to understand energy management in buildings. It is also important for the technological impact it provides to users [22]. This research analyzes the energy management in smart buildings in Peru through methodologies such as the review of articles published in the Scopus database using the VOSviewer software as a data analysis tool. This analysis has a period from the XXI century to the year 2021. Graphs related to the research of the database were obtained where the words "intelligent building" and "energy management" are highlighted with greater congruence and mentioned in these journals. Figures were obtained worldwide and in Peru. The results allowed us to understand that smart buildings are becoming more important in developed countries and opening new markets since there are unmet needs of users. In the analysis of Peru, the opposite happens since there are minimal scientific contributions related to the subject. They still do not have intelligent buildings 100% but there are some buildings where energy management is carried out in minimum proportion. An energy management software related to big data called smart building was also found, which has the objective of managing energy consumption in each building to reduce the carbon footprint emitted by buildings. This research is intended to guide you to start with in-depth research and implementation projects for engineers and architects interested in developing and managing intelligent edifications. Nowadays, the importance of studying this topic is to take care of the environment as social and professional responsibility. For this reason, the professionals should opt for better strategies for energy management thus positively impact Peru.

Keywords Smart Buildings, Energy Management, Internet of Things, Bibliometric Analysis, Smart City

1. Introduction

At a global level, a record in carbon emissions was obtained in the building sector in 2019. This sector "produced 38% of global CO_2 emissions related to energy" and in 2020 they were reduced by 20% and 30% to the previous year and with it obtained 10% of completion in the construction area [1]. Buildings "are responsible for almost 40% of carbon emissions and consume 50% of the materials extracted from the environment". It is also claimed that 91% of the population live in polluted areas and 4,000 million people are vulnerable to climate hazards worldwide. It is highlighted that by 2050 twice as many buildings will be needed and greater natural resources will be required [2].

In Latin America, there are great changes in construction. Brazil, Argentina, and Chile implemented strategies in favor of the use of sustainable buildings by enacting laws and certifications for their use in each country, and in countries such as Mexico and Colombia, there are also development strategies, but until now there is no correct use of the rules and regulations for the practices and implementation of sustainability in projects of construction [3].

Peru is the third country with the highest vulnerability to climate change and is in the initial stages of implementing efficient energies for the construction of buildings, demonstrating the lack of environmental awareness among professionals in the area [3]. In addition, according to the Ministry of Energy and Mines, 35% of electrical energy is diversified into the following sectors: "residential sector 15% to 30%, commercial sector approximately 33%, public sector approximately 24% and industrial sector 10% to 15%" [4]. A study of 2500 people in the residential sector in the city of Lima also shows that the electrical appliances that consume the most energy are the refrigerators at 55.3% of electrical energy, followed by lighting and television, where they concluded that the Peruvian population is unaware of energy management [5]. For the reasons mentioned in the comparison between Peru and Latin America, this article aims to determine if there is energy management in smart buildings in Peru and to know the application methodology to manage energy in a building.

To this end, a bibliographic analysis was carried out using the VOSviewer tool of scientific articles carried out on the same topic worldwide and at the Peruvian level. The results section contains the following subsections: Item one biometric analysis of energy management, item two platforms for energy management, and item three scenarios actual of energy management in smart buildings in Peru.

2. Materials and Methods

This scientific contribution is the bibliographic compilation of scientific publications focused on energy management in smart buildings. The development used the scientific tool offered by Scopus and according to Falagas, the main scientific journals with scientific and technological advances give legibility to the results [6].

First, the bibliometric mapping of scientific activity was used, which is the VOSviewer. This software serves to analyze and produce maps based on data mining of scientific activities in each research area [7]. The extracted data were in files (.csv) that were obtained from the XXI century of 2000 until November 30, 2021 from the Scopus database. The methodology and search criteria were carried out as follows:

(a) First, the data were collected from 2000 to 2021, with the search criteria of "intelligent building" and "energy management", in documents, articles, reviews, and conferences. 2,658 documents were detected worldwide.
(b) Second, data were collected from 2000 to 2021, with the search criteria of "intelligent Building" and "energy management", in documents, articles, verifications, and conferences. Two documents were detected at the level of Peru.

Figure 1 was obtained with the information obtained from points a) and b). This data was passed to the VOSviewer software, which resulted in Figure 2 and Figure 3. These data obtained are the highlights of this research.

Second, a collection of information from energy management software was carried out providing tools for the management of intelligent buildings. A monitoring system manages to integrate, process, and analyze different variables that make up the environment, social and economic [8]. The data generated by observation are sources of valuable information to make decisions in the infrastructure having closer contact with the user [9]. The tools must provide the data obtained in real-time. It must also have mathematical sessions that provide flexibility, scalability, and versatility, allowing for analysis of current and real-time data in an agile and intuitive way, which is big data technology [8].

In Table 1, the first integration function is responsible for eliminating data independent of technology to join heterogeneous data, where sensors are used to measure temperature, alarms, and also energy consumption. The data that enter are processed with the second function that allows statistical calculations in real-time and historical which are calculated using big data and among other tools. In the end, the analysis is the analytical result of everything processed that gives us the information in real-time, graphs, tables of results that is manifested with notifications and alarms when it exceeds the maximum of each day and the final value is the presentation of the data in a systematic and understandable way.

Table 1. Structure of the energy management platform

INTEGRATE	PROCESS	ANALYZE
Sensors	Business processes	Graphs and analysis
security	Calculation	Analysis in real-time
Temperature	Bigdata	HMI dynamic graph pictures
Inflows	Statistics	KPI dashboards
Alarms	Data reconciliation	BI reports
Refrigeration	Historical data	GIS maps and interactions
Energy consumption	Olap	Calculations and BPM
Illumination	Real-Time	Alarms and notifications

Note: In Table 1 we observe all the processes carried out by an energy management platform through the integration,

process, and analysis steps. For this, it is necessary to have a historical database. (Rodriguez and others, 2021)

3. Results

3.1. Biometric Analysis of Energy Management in Smart Buildings

Twenty years ago, the worldwide scientific journal Scopus had minimal research related to "smart buildings" and "energy management". But from 2010, the research was gradually ascending. In the beginning, the engineers and researchers took a greater interest in the subject. Figure 1 shows the growth of research from 2000 to 2021 and the year 2020 is found with 535 documents.

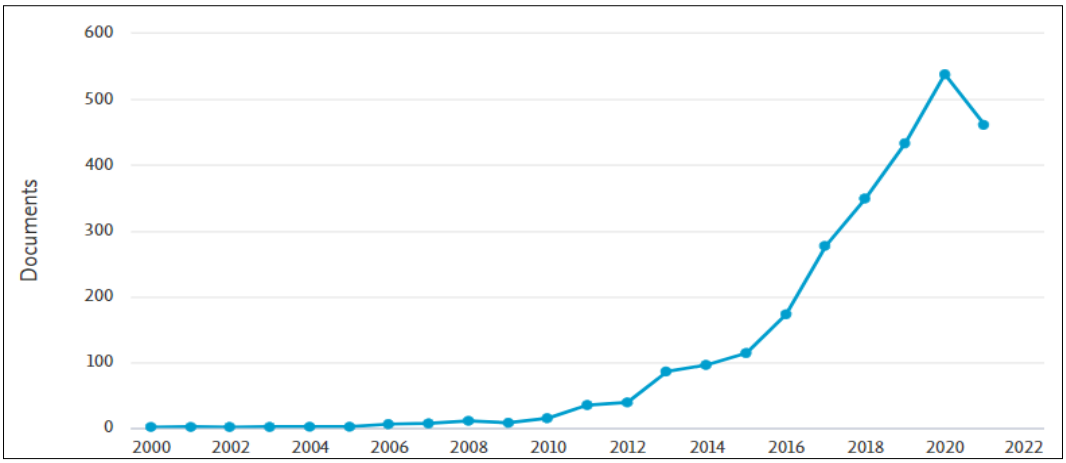

Figure 1. Scientific growth in the field of energy management in smart buildings worldwide. Source: Scientific review Scopus.

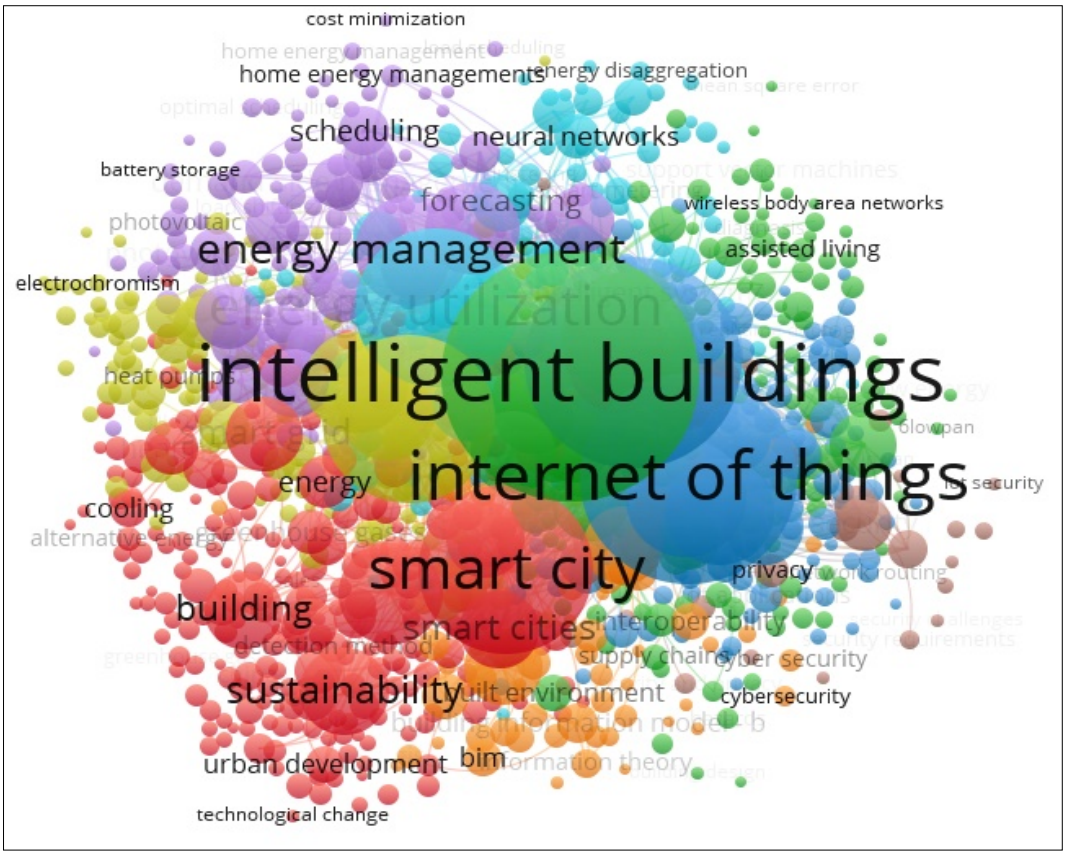

Figure 2. Map of most used words of the title, summary of scientific contributions in energy management and monitoring for smart buildings. Source: Obtained from VOSviewer

In the map of terms shown in Figure 2, the analysis of data mining carried out with the VOSviewer software is observed. All the information is extracted from Scopus. The highlight of the terms is "intelligent buildings" with greater interaction, the second term is the "internet of things" and the third term is "energy management". The colored circumferences show the trend and the relationship with the other investigations. The relationships are demonstrated in Figure 2, which show that the investigations in intelligent buildings have a great relationship between energy management and the intention of things.

In 2021, only two documents related to energy management in smart buildings in Peru were found, which were analyzed using the VOSviewer software. All the information is extracted from Scopus, and the outstanding term is "internet of things" related to construction, as can be seen in Figure 3.

3.2. The Platform for Energy Management

The TEAC software serves to predict the heating demand and energy consumption with the energy plus outputs in numerous buildings. This software allows for improvement and plans sustainable energy solutions in large cities and is difficult to measure. In the application case of the article, it mentions that they used photovoltaic panels thus reducing energy consumption by 57% and consequently the CO_2 emissions ratios about 89% [10]. The smart buildings management platform contains a business management system (BMS), which fulfills the objective of monitoring, controlling, reporting through graphic samples and the functions they fulfill are generating automatic schedules and sequence of events, statistical operations, configurations, and management of alarms, ON / OFF shipments, regulate energy and also manage maintenance such as preventive, predictive and corrective [8].

In Figure 4, the technological support platforms are observed. These are: the BPM increases the volume of the business and improves customer service; the BMS increases the useful life of the facilities and the automation of processes focused on user satisfaction; and the SGE manages, locates and optimizes energy consumption to integrate all the above and have as results kPIs (Key Performace indicators) for efficient operational control [8].

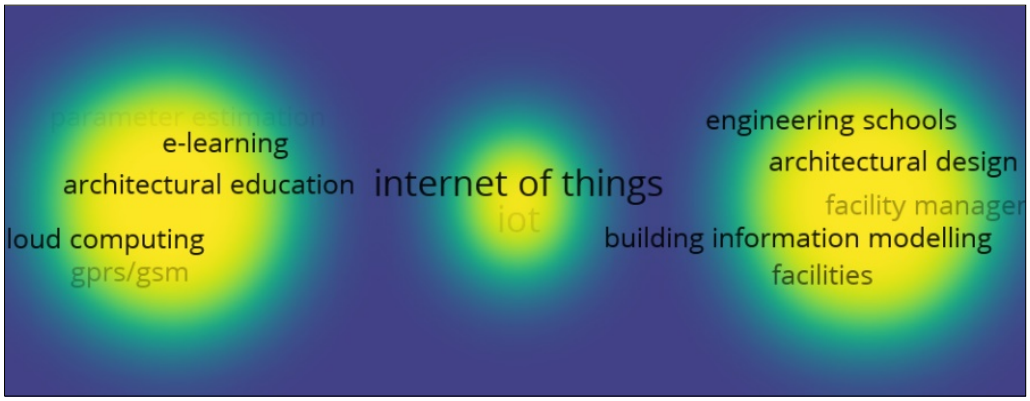

Figure 3. The scientific evolution related to energy management in smart buildings in Peru. Source: Source: Obtained from VOSviewer

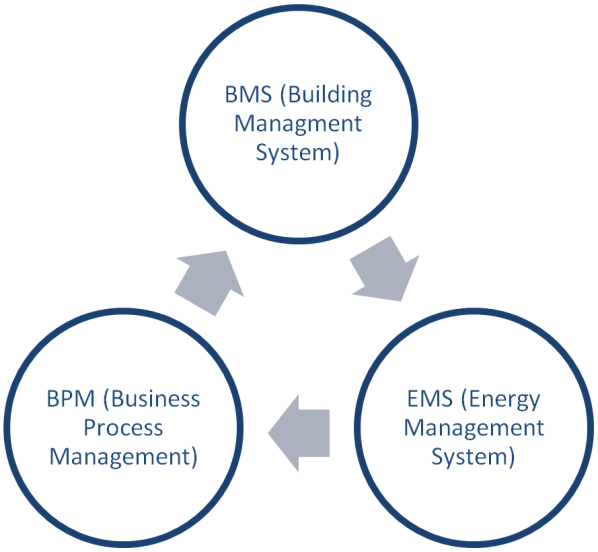

Figure 4. Smart Building Applications. Own source.

Table 2. Requirements of smart buildings.

N°	Objectives	Descriptions	Technical requirements
1	Location-based services	Identify the location, resources, and movements of buildings to improve the comfort of services.	Track the location of objects.
2	Energy efficiency	Maximize energy use and maintain a high level of service at the same time.	Communicate with external elements
3	Installation Management	Preventive maintenance, organized operation, control of construction facilities. The equipment to reduce processing operations, time, and cost.	Establish communication between buildings, equipment, and devices
4	User comfort inside	Optimize the environment according to the user, improve health and productivity.	Understand the pattern of behavior of users.

Smart building has the function of uniting the building systems, connecting the user with technology, managing energy expenditure, building control, and is connected to a smart grid [11]. It also optimizes and improves data collection using sensors, interacts with the user through apps, and analyzes the information obtained for continuous improvement [12]. All the mentioned, thanks to the Internet of Things (IoT), are "Devices connected in a network with digital interaction that collects data, from a system with environmental control to an autonomous system". It also mentions that by 2023 50% of connections will be to IoT devices and it is related to smart buildings since they facilitate the improvement service. The IoT is facing great changes since 5G technology will provide private communication which is becoming a technology with great growth and transformations for the future [13].

In addition, the opportunities offered by 5G in smart buildings are business opportunities, because the demand for broadband data will increase significantly in the use of times. By using 5G, you can connect to several services with good data transmission, actuators and sensors, which will allow us to obtain an automatically managed building [14]. Table 2 shows the requirements and functions of smart buildings.

3.3. Stage in Peru

In the article on energy efficiency, sustainable urbanism, and agenda 2030, it mentions that the 70% of population and 90% of their lives are inside the home carrying diseases due to internal air pollution. For this, the national energy and climate plan in Spain have objectives to comply with "that 42% of renewables, 39.5% in improvement in energy efficiency and 74% of renewable energies" through campaigns on information and consumer training [18]. In this way, we understand that the buildings will have greater relevance. Also in Singapore, they aim to achieve "a greater possible return with the slightest investment", in the construction sector since they consume a third of all energy in Singapore, which is a good investment because it will reduce the carbon footprint [14], in addition to the change in building materials, reduce energy consumption to mitigate carbon emissions and recover the economy [1].

In the current scenario of smart buildings in Peru, there are smart buildings that have certifications such as "LEED (Leadership in Energy and Environmental Design), the VERDE certification (building efficiency assessment of building reference), and the BREEAM certification (Building Research Establishment Environmental Assessment Method)". The buildings are the following: Hotel Westin, New headquarters of the Banco de la Nación, national library, UTEC, Thin Clinic, Interbank Tower among others to mitigate CO_2 emissions [15]. In addition, energy management according to the energy and business magazine mentions that "Peru consumes between 8 and 10 times more electrical energy than 20 years ago which can cause future problems to the electricity grid", which implemented the M1M and M4M multifunctional meters that control the electrical parameters to generate energy efficiency reducing up to 30% in the cost in the industries, buildings, and residences [16].

In a study conducted in Peru, the methodology used was hypothetical-deductive and the realized instrument was the survey. They found that 72% of respondents are in favor of the integration of the internet of things in their buildings, allowing control of communications and energy efficiency in buildings where it recommends that the Peruvian government dictate rules regarding smart buildings [17].

4. Discussion

Documents like this allow us to contribute to the scientific community on the impact towards a future that it can generate for a growing society like Peru. In this scientific contribution of bibliographic review, measuring the VOSviewer tool was possible to determine that the worldwide word "intelligent buildings" is related to "energy management" and the level of Peru two documents referring to "The Internet of Things" were found. Opting for energy management in smart buildings represents a greater investment and additional expenses for the operation at the beginning of the operation of the buildings. According to the bibliometric analysis, the scientific community in Peru does not show great interest in energy management or reducing energy consumption, which is a

barrier to entry for future smart buildings. Likewise, in the study on energy management based on the standard in a university, they determined that both students and professors are not aware of energy control demonstrating the misuse of energy as example lights turned on in laboratories and equipment turned on for long times even so they are not using it sim. However, they plan to implement an energy control system to improve energy consumption in the university.

Climate change forces us to take measures against construction. A fact of construction is that it is possible to "reduce 40% of the emissions of the construction sector with current market technology" [19]. Also due to the increase in solar temperature, future problems generate a negative impact that will limit us to consume fuel and energy in order to reverse the carbon footprint in buildings [19]. In addition, the increase in energy use and environmental deterioration cannot be solved in a short period of time. For this reason, technologies, renewable energy sources, and government support are required to reduce the gap [24]. For these reasons, energy management tools in smart buildings manage to have greater value in future sustainable constructions.

The scope and optimization of energy in smart buildings together with the intelligence of things (Iot) manages to give an opportunity for engineers in Peru since according to IT magazine, smart buildings will grow from 11% to 16% year-on-year, generating great opportunities in construction [20]. In most countries, measures were taken to mitigate global warming and the carbon footprint as the main cause [25] is also related to human activities. The author recommends implementing intelligent sensors for the measurement of consumption and the factors that surround it including statistical analysis [26]. Likewise in Latin America, there is no building that is 100% intelligent. This opens opportunities in the case of new buildings, which requires a robust infrastructure with lighting, video cameras, sensors, air conditioning and among others, with the first objective of being friendly to the environment, second to complement and modify the buildings that exist to convert it at least 50% into an intelligent building.

5. Conclusions

The contribution of this research is observed in the results obtained which are: first, in Peru there is minimal research on the topic of energy management in smart buildings, second, the research on the subject has increased in the last three years, third, the fields of research related to energy management in sustainable buildings are the internet of things and smart city and finally, there are technologies such as Big Data and Smart Building to manage energy in smart buildings. All the above is limited to the source of bibliographic information Scopus which can be accessed and gives us the analysis. At present, there are many buildings such as hotels, hospitals, clinics, offices and among others that are implementing smart buildings either 100% or 50% in potential countries, which aim at energy efficiency [21]. We conclude that in Peru it is possible to build and adapt intelligent buildings with the aforementioned technologies generating a positive impact on the environment and reducing the carbon footprint of Peru. We recommend opening new paths to investigate the social, technological, political, and economic barriers that Peru has in the face of the construction and adaptation to smart buildings.

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