THE INTERNET OF THINGS AS AN ESSENTIAL ELEMENT FOR THE BENEFIT OF THE ENERGY SECTOR: A REVIEW OF THE LITERATURE

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ABSTRACT

The Internet of Things is an important element of Industry 4.0, which has brought innovative technological contributions to the energy sector; Industry 4.0 allows organisations to transition to intelligent companies through the use of the Internet of Things and technologies that favour manufacturing and production processes to be more efficient. The aim of this paper is to identify how the application of the Internet of Things has had benefits in the energy sector. This paper presents a literature review in a traditional way, to identify the importance of the Internet of Things and its application in the energy sector in the field of wind, solar, hydroelectric, and fossil energy. The analysis of the literature shows that there are studies that indicate the benefit of the internet of Things in the energy sector, with 48 documents being recognised, of which 25 publications belong to the year 2022.

OPSOMMING

Die Internet van Dinge (IoT) is ‘n belangrike element van Industrie 4.0, wat innoverende tegnologiese bydraes tot die energie sektor gebring het. Industrie 4.0 stel organisasies in staat om oor te skakel na intelligente ondernemings deur die gebruik van IoT en tegnologieë wat vervaardigings- en produksieprosesse bevoordeel om doeltreffender te wees. Die doel van hierdie artikel is hoe die toepassing van IoT voordele in die energie sektor gehad het, te identifiseer. Hierdie artikel bied ‘n literatuuroorsig op ‘n tradisionele manier aan om die belangrikheid van die IoT en die toepassing daarvan in die energie sektor op die gebied van wind, sonkrag, hidro-elektriese, sowel as fossiel energie te identifiseer. Die ontleding van die literatuur toon dat daar studies is wat die voordeel van die IoT in die energie sektor aandui, met 48 dokumente wat erken word, waarvan 25 publikasies in 2022 was.

1. INTRODUCTION

The energy sector encompasses processes of conversion, extraction, transmission, and distribution of energy in sectors such as industry, transport, agriculture, forestry, and construction.

The energy sector is currently going through a process of technological globalisation, which opens it up to the challenges and opportunities driven by Industry 4.0 and to solving the need for sustainable development. Technological globalisation and Industry 4.0 drive the energy sector to adapt quickly to new technologies and to face complex problems in areas such as sustainability, cybersecurity, regulation, and workforce training, while seeking to take advantage of opportunities to improve efficiency and to reduce the environmental impact. This technological breakthrough not only transforms the way energy is produced and consumed, but also addresses crucial needs for sustainable development. Technological innovation in the energy sector plays a crucial role in achieving global goals related to sustainable development, especially in the promotion and adoption of renewable energies. These innovations range from improving the efficiency of solar panels and wind turbines to developing advanced energy storage technologies, such as lithium-ion batteries and grid storage solutions. In addition, digitalisation and the use of artificial intelligence in energy management allow for real-time optimisation of energy distribution and consumption, thus reducing losses and improving the overall efficiency of the system; likewise for mechanisms that guarantee a favourable innovation ecosystem based on neo-industrialisation [1].

The Internet of Things (IoT) enables the interconnection of devices and systems, facilitating real-time data collection and analysis. This improves efficiency in energy production by optimising the use of resources and minimising losses. In respectpredictive maintenance, IoT sensors can detect anomalies and predict failures before they occur, reducing downtime and repair costs. In addition, Industry 4.0, through the use of advanced technologies such as big data analysis and artificial intelligence, improves the monitoring and control of energy systems, allowing for more precise and efficient management and for informed decision-making to increase productivity and sustainability.

Energy is essential for the economic development of a country. However, the ability to perform a sustainability analysis of their digital transformation was quite limited. With the intervention of Industry 4.0, changes are taking place in digital transformation, focused on social aspects of manufacturing and organisation such as the application of emerging technologies, artificial intelligence, the IoT, augmented and virtual reality, data analytics, robotics, and automation [2]. The intervention of Industry 4.0 in industrial processes has generated greater digitalisation in organisations, based on intelligent and interconnected production through implementing the IoT [3]. The energy sector has seen technological growth with the implementation of electronic devices that help to solve the demand for energy and that generate changes in prices for organisations in different countries [4, 5, 6].

The purpose of this study was to identify how the IoT has benefited the energy sector from a traditional literature review approach, and to identify how new technologies are applied in Industry 4.0, supported by the literature being analysed, through bibliometric research. The databases used to obtain the information were Scopus, EBSCO Essential, MDPI, and Taylor and Francis.

There are digital innovation platforms that are focused on the energy sector with the ability to generate value and innovation in their ecosystems, resulting in the formation of different disciplines of interest in global trends, such as digital transformation and Industry 4.0 [7]. Digitalisation has presented results of continuous improvement in productivity of 3% to 5% per year, improving costs above 25%.

The implementation of innovative state-of-the-art strategies strengthens the direction of the actions taken in managing companies, and increases the reliability of technological solutions that have increased the useful life of a power plant by 30%. The intervention of technologies such as Blockchain and Industry 4.0 have made it possible to increase energy efficiency and to produce actions for better organisational management (Table 1) [8].

Table 1: Direction and developmental elements of the energy sector

Elements	Applications
A) Decarbonisation	A1- Renewable energy companies (RES)
	A2- Nuclear energy
	A3- Alternative Fuels
B) Sustainable development	B1- Energy efficiency
	B2- Increased flexibility
	B3- Eco-mobility
C) Digitalisation	C1- Digital twin
	C2- Radio frequency identifier (RFID)
	C3- Internet of Things (IoT)
	C4- Blockchain
	C5- Virtualisation

2. LITERATURE REVIEW

Digitalisation opens up new opportunities to improve energy efficiency through the application of data mining and information analysis. With the use of artificial intelligence (AI) algorithms and the integration of IoT technologies, it is possible to optimise energy consumption more effectively. the IoT enables the real-time collection of data from connected devices, facilitating more detailed and accurate analysis that, combined with AI, can anticipate and respond to energy needs dynamically, reducing waste and improving the sustainability of the energy sector [9]. This research aimed to analyse the importance of Industry 4.0 (I4.0) and its application in the energy sector. For this reason, a systematic review of relevant research in which I4.0 has been applied in different areas of the energy sector was carried out.

2.1. Industry 4.0 in the energy sector

I4.0 has provided innovative technological breakthroughs for the energy sector that represent new opportunities for improvements in organisations. I4.0 brings with it the transformation of organisations' conventional production systems into intelligent systems with technology intervention. Technological changes have improved the functioning of different industrial processes as a result of the generation of efficient and innovative companies [10]. Organisations are seeking to achieve sustainability in their production processes and, through the intervention of new technologies such as I4.0, to reduce the level of the greenhouse effect in order to avoid disasters and irreparable damage to the environment. The energy sector has been gradually incorporating automation and business connectivity to make manufacturing processes more agile, flexible, innovative, and pvisible to customers [11] [12]. This trend towards automation involves implementing advanced technologies such as artificial intelligence, the IoT, and big data analytics. These technologies make it possible to optimise resource management, improve operational efficiency, and reduce costs.

2.2. Wind energy

Wind energy is a form of renewable energy (RE) that, in the last decade, has advanced efficiency through the use of effective controllers with the ability to regulate the power it generates [13]. Wind energy is an accessible way to generate kinetic energy and transform it into electrical energy. It is increasingly used in obtaining renewable energy, using advanced technology such as controllers, converters, and modern generators that are integrated with wind turbines [14].

One element of I4.0 that has brought benefits in wind energy harvesting is the IoT. The combination of a system based on the real-time environmental monitoring of humidity and temperature and a wind-driven electromagnetic energy harvester with a pair of rotational magnetic poles has provided results that can be sent in real-time to a smartphone. This innovative system is a technological breakthrough in the transformation, for example, of standard agriculture into smart agriculture, since the maximum energy efficiency is 73% [15].

The manufacture of intelligent technology, intelligent processing, and information communication has brought the IoT to a new level of intelligent evaluation [16], and has achieved an increase in the performance of information management and analysis. IoT-based systems with cloud computing and big data analysis present an important approach to the field of wind energy as a promising, environmentally friendly and clean source of renewable energy. Productivity, efficiency, operating costs, and profitability are parameters that require a system with the ability to maintain high performance over a long period of time. IoT is perceived as a key technology trend for sustainable growth in the renewable energy sector. Wind energy in particular benefits greatly from these innovations, enabling more efficient resource management, reduced costs, and maximised energy production, thus securing its position as a key solution in the transition to a more sustainable energy future [17].

The high-performance triboelectric nanogenerator (TENG), based on the IoT and with the ability efficiently to collect wind energy for distribution, is a new-generation technological energy solution. Energy solutions and the IoT are in high demand in this I4.0 approach, with features to power wide-range sensors. Wind energy is considered an ideal energy source for distributed devices and sensors owing to its great advantages of being sustainable and renewable [18]. The conversion and distribution of wind energy has brought a global technological revolution by generating renewable energy through the use of power conversion systems (WECS), which feature advanced multi-level inverters (MLIs) to develop wind technologies [19].

The IoT is a crucial element in improving the reliability of renewable energies. It has been the main objective in improving wind turbines, thus reducing energy costs and risks. However, using the IoT is a difficult task, as it is necessary for the level of the wind turbine to be monitored in real time [20]. With the intervention of the IoT, automation and artificial intelligence is enabled, using systems that are smart, reliable, efficient, and able to eliminate global energy problems [21]. Although wind energy has some instability that is derived from the weather, climatic zone, time of day, and season of the year, the intervention of new technology helps to generate greater reliability and quality in energy; and better wind prediction is achieved through the use of deep learning (DL) and the IoT [22].

The global need is for renewable sources of energy that meet the demand for electricity, such as wind and solar power, which are vital to combat climate change. The technologies that accompany I4.0 have proven to be effective in pursuing the benefits of wind energy and achieving a reduction in pollution [23]. The IoT manages a large infrastructure of web-enabled smart devices – small devices that use embedded systems, such as processors, sensors, and communication hardware – to collect and send data that is acquired from their environment. Energy harvesting plays an important role in increasing the efficiency and lifespan of IoT devices; thus it is important to make the IoT environmentally sustainable [24].

The IoT as an element of I4.0 arises from an intelligent approach that helps to manage renewable energies with excellent possibilities for progress in improving the reliability of wind energy conversion systems, different turbine operation scenarios, and the design of algorithms for better control [25].

The integration of wind energy into I4.0 aims to optimise resources and manage energy production intelligently. Automation and data analytics could improve the efficiency and reliability of wind farms.

2.3. Hydroelectric power

Large hydroelectric power plants are dedicated to obtaining the greatest amount of electrical energy from the power of water. There are currently hydraulic infrastructures that have the capacity to exploit the potential of this renewable resource at up to 95% of total yield [26][27]. Hydroelectric power plants have important elements [28] that together have the capacity to convert the potential electrical energy contained in a given body of water as it moves at two specific points at a certain height (Figure 1).

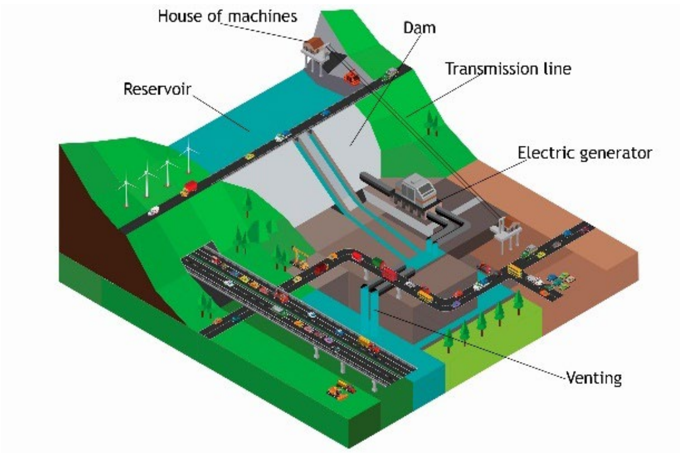

Figure 1: Main elements of a hydroelectric power plant

A solution that has helped rural areas in the field of energy are peak-type hydroelectric plants based on the IoT. This technology helps to monitor the flow rate of river water through monitoring systems (WAFLOW-MT) and water flow sensors. The information collected by the system is sent to web servers in real time for analysis when the WAFLOW-MT monitoring system has presented a successful water flow monitoring response [29].

Hydroelectric power plants are power renewal plants that have the highest installed capacity in the world. New technologies such as the IoT and machine learning (ML) have the ability to detect problems in real time and to ensure an effective solution for proper operation. There are systems that, through the intervention of analogue evaluations, detect errors caused by some condition in the operation of the system. There are also learning methods that, by applying the supervisory control and data acquisition (SCADA) system, which has the capacity of machine learning to predict problems with up to 96% success, eliminates early anomalies and takes precautions in an appropriate way [30] [31].

The goal of obtaining renewable energy sources has become fundamental to reducing carbon emissions worldwide. Hydropower in some countries, such as Bangladesh, is located in specific areas, and is used to assess the capacity and viability of this energy by implementing combined cycle hydropower systems, which would help the plant to generate a significant amount of additional electricity with greater efficiency throughout its process [32].

While many countries are innovating with the new technologies offered by I4.0, there are difficulties such as those faced by Nigeria and many other countries in Africa, where energy poverty is more widespread in rural communities, as only 36% of the population has access to electricity. Small hydropower plants are being considered as a viable and sustainable solution for rural areas in Nigeria. Not only are these projects easier to implement with geographic information systems (GIS) technologies, but they also meet environmental requirements by reducing dependency on fossil fuels and minimising the ecological impact.

With new technological advances in GIS and remote sensing, hydropower site identification has become accessible, fast, and cost-effective as clean energy that meets economic and environmental requirements. GIS and remote sensing technologies are revolutionising the way in which hydropower projects are identified and developed. These tools make it possible to map potential areas for hydropower projects with unprecedented accuracy and speed [33].

Another important objective of hydropower is to improve the safety of hydraulic structures in hydroelectric power plants for which there are smart designs, schemes, and connections based on the IoT. This type of hydraulic equipment monitoring connection is made through a communication network, a real-time monitoring application, and system information security in order to ensure the efficiency of the operation of the hydropower plant infrastructure [34].

Although the construction of a hydropower plant is a long-term project, the IoT and I4.0 technologies can play a crucial role in all stages of the project, from initial planning to ongoing operation and maintenance. These technologies enable better data-driven decision-making, resource optimisation, and improvements in plant efficiency and sustainability.

I4.0 has a contribution to make in new technologies to hydroelectric energy and sustainable development, guaranteeing environmental security for the future. Clean energy, affordable energy, and infrastructure innovation are important elements that today are part of the objectives of sustainable development that are applied to the energy sector [35].

The application of advanced technologies such as the IoT, artificial intelligence, and data analytics enables a more efficient and accurate management of hydropower plants. This leads to an improvement in operational efficiency, reducing costs and optimising the performance of power generation. In addition, the integration of hydropower into an I4.0 environment facilities greater flexibility and adaptability of the energy system, allowing a better response to fluctuations in demand and greater integration with other renewable energy sources.

2.4. Solar energy

The solar panel is a device that converts electromagnetic radiation obtained from the sun into electrical energy for the operation of any system [36]. The biggest advantage of solar energy systems is that, like other renewable energy sources, they do not have negative effects on the natural environment [37], [38].

There are models for the control and analysis of smart solar energy consumption, based on the IoT, through the use of solar energy from micro-photovoltaic grids. The IoT design meets product and process requirements. Solar panel energy adequately addresses important aspects of production processes. This should include risks related to product quality and safety [39].

Not only is the safety and quality of a product important when talking about the IoT in relation to solar energy, but also having the assurance of a good quality management system that can evaluate the effectiveness of solar consumption [40][41].

Through the intervention of the IoT, bluetooth, and blockchain technique, platforms such as EggBlock have been generated to promote the trading of solar energy among users who have solar panel equipment. This platform proposes a dynamic based on Q-learning, which is a real-time panel control mechanism with which it is only necessary to establish the direction of the solar panel and the amount of energy generation such as the status and the reward respectively. The intervention of the IoT in this system presents an average energy generation gain of 35% [42] [43].

Solar power plants are installed in remote locations; therefore, it is necessary to have a remote monitoring and control system that has web-based interfaces with technology based on the IoT, which allows for real-time information on solar irradiance, temperature, clarity index, panel voltage, current, peak power, and tilt angle of the solar panel to be monitored in order to maximise photovoltaic energy using a genetic algorithm. The development of an IoT-integrated solar power plant with hardware configuration can improve the performance of the proposed system. The IoT-based control of the solar power plant significantly improves the performance of monitoring and the maintenance of power plant parameters with cost-effectiveness [44].

As long as there is an interest in implementing new technologies, the management of the electricity generated by solar panels relies heavily on the IoT. While it is challenging to create smart, practical, and affordable condition monitoring, protection, and control systems for residential distribution networks, there are also mobile apps that allow individual users to monitor the system in real time, to alert users about electrical system issues, to display real-time energy usage, and to provide other essential alerts and warnings [45] [46]. Forecasting photovoltaic power generation is of great importance for maintaining grid security and coordinating resource use. In the age of big data, it is possible for IoT technology to be powered by AI to generate accurate solar energy [47].

To meet the world's need for energy consumption, we need to find better and more stable alternative forms of renewable energy with advanced technology. The most readily available energy source is solar energy, in conjunction with techniques such as artificial neural networks (ANN) and fuzzy, which are more accurate techniques based on forward/backward propagation and multiple layers, linear regression with an ANN model, and a GNN graph neural network-based model. The use of fuzzy logic and ANN models has been more effective in estimating energy consumption and in optimising results in real time [48] [49].

The energy industry is undergoing major changes with the intervention of I4.0. In addition, innovative business model strategies have enabled access to electricity and the benefits that solar energy offers today.

The convergence of solar energy and I4.0 offers a range of innovative benefits. By integrating technologies such as the IoT, AI, and data analytics, solar installations can be optimised to maximise production and minimise operating costs. This translates into greater energy efficiency and a reduced reliance on non-renewable energy sources. In addition, digitalisation enables real-time monitoring and predictive maintenance, improving the reliability and availability of solar energy. The combination of solar energy and I4.0 technologies also promotes energy decentralisation and system resilience by enabling a smoother integration with the power grid and smarter demand management.

2.5. Fossil fuel energy

The oil and gas (O&G) industry is highly complex, and uses highly specialised equipment, tools, and assets. In recent years, the trend in that industry has been to integrate digital technologies into the O&G extraction process as the performance of information technology (IT) has increased and the price has decreased. IoT solutions applied in the O&G industry have optimised the information that is generated by infrastructures through the integration of sensors, communication channels, and data analysis to ensure effective security [50].

The application of the IoT is considered a new technological concept in the O&G industry, which provides a high level of security by detecting faults in real time. It reduces the costs of production processes, such as exploration, search, monitoring in the oil industry, in order to optimise and ensure a highly productive performance [51].

The I4.0 concept has become part of a global revolution, which has been led mainly by the manufacturing sector. The continuous process industry is part of this global trend, in which there are aspects of I4.0 that must be adapted to it, such as oil refineries that have evolved through control supported by specific technologies based on the IoT and AI. These can overcome the current limitations of advanced control systems by providing better performance in highly nonlinear and complex systems, operating with a wider reach in respect of signals/data [52].

The IoT has changed the landscape of O&G. Recent research by Inmarsat Research found that nearly 74% of O&G companies have implemented at least one IoT project, and an additional 81% indicated that they planned to accelerate their IoT adoption in response to difficulties related to the recent global pandemic.

Another innovative technology is the intervention of private 5G networks in support of advanced solutions that improve safety in the workplace. O&G companies can apply smart-edge solutions to monitor safety risk breaches. IoT sensors can detect gas leaks in equipment, temperature fluctuations, and vibrations to prevent catastrophic events while keeping employees safe. From a sustainability standpoint, private 5G enables solutions that help to prevent O&G leaks, reducing their environmental impact, and that implement smart solutions that minimise the use of energy and resources to reduce emissions in the field.

The 4IR, digital transformation (DT), the IoT, and AI have become valuable tools in the O&G industry. DT in O&G requires the union of physical technologies, such as smart sensors, with cloud-based digital technologies – a union that forms the basis for the IoT. Drilling companies benefit from the implementation of the set of IoT-related technologies; although they focus on the costs that are saved, they also emphasise the great potential that these technologies should have in the future to increase their efficiency in generating revenue and profits, performing tasks differently in a traditional industry such as drilling [53].

The collapse in oil prices in mid-2014 and in early 2016 was the largest in modern history, causing a drop of more than 70% in the price of a barrel, prompting O&G companies to think seriously about maintaining their profitability. Most companies were able to survive in part because of the simplification of their operations. The price recovery in 2021 reached only 70% of its peak value. Companies have thus focused on reducing the cost of operations while simultaneously increasing production and finding new and different strategies to survive, such as with the practical solution of the IoT, which improves the oil production rate of the well and increases the average pump (filling) efficiency to 90% [54].

Other main technologies are submarine wireless sensor networks (UWSN) that are related to environmental monitoring, underwater O&G extraction, military surveillance, smart agriculture, and communication, among other activities. It is worth mentioning that this type of technology is prone to major problems, such as a limited network lifespan, the low processing capacity of nodes, high power consumption to execute routing protocols, and the difficulty in replacing ganglia; but they meet the goal of reducing power consumption [55].

A management information system (GIS) for the storage and transportation of O&G, based on the IoT, is being used to analyse accurately the route planning of O&G pipelines, as well as for O&G production scheduling, the statistical analysis of O&G data, and other functions that have helped organisations to have real-time control, with benefits in the optimisation of industrial O&G processes [56].

The application of I4.0 technologies in the fossil energy sector can bring significant improvements in efficiency and safety. Through the integration of sensors, data analytics, and advanced automation systems, operations in fossil energy extraction, refining, and distribution can be optimised to reduce costs and minimise operational risks. In addition, the implementation of real-time monitoring technologies allows for a faster response to market fluctuations and consumer demands, thus improving the flexibility and adaptability of the energy sector. However, it is important to consider that fossil energy, despite technological improvements, remains a non-renewable source and contributes to greenhouse gas emissions, underscoring the need to continue moving towards cleaner and more sustainable energy sources.

In the I4.0 era, wind energy has stood out for its ability to generate electricity more efficiently, thanks to advanced technologies that integrate it with intelligent energy management systems. Although fossil energy sources remain critical in several industrial sectors, cleaner and more efficient alternatives are being developed to reduce their environmental footprint and to improve their adaptation to I4.0. Hydropower, especially in areas with an abundance of water, is emerging as a viable option, focusing on optimising production and managing energy intelligently. On the other hand, solar energy has experienced remarkable growth in this context, thanks to advances in photovoltaic technology and energy storage, providing greater autonomy and efficiency in industrial processes. Together these energy sources are merging with digital technologies and automated systems to enhance efficiency and sustainability in I4.0, promoting greater competitiveness and a reduction in environmental impact.

3. METHODOLOGY

3.1. Literature search

The search for information in the literature was based on queries of scientific articles, repositories, and specialised databases. The topic was identified in English and Spanish articles in which concepts related to I4.0 and its relationship with the energy sector were presented. Publications from the last 12 years were considered. The search of the literature in the traditional way was deepened: databases were identified and topics related to the present study were searched. Table 2 details the search mechanism to obtain information using the following data: author's name, journal where the research work was published, year of publication, keywords, and country where the research was developed or applied.

We chose to use the PRISMA method [57] as a starting point to carry out the systematic review process. This method uses a flowchart (Figure 2) as a model for the organised presentation of the information that was examined. In the context of this research, a review of the initial 217 documents was carried out, prioritising their importance in relation to the research topic. During this process, 45 documents were discarded because of duplication or similarities. Of the remaining 172 articles, a comprehensive review was conducted by experts in the field. At this stage, 60 documents were excluded because they did not meet the objectives of the research, 17 because they did not fit the target population, 22 because they lacked significant applications in the area of engineering, and 25 because they were not relevant in the information they provided. Consequently, only 48 texts were assessed for suitability and inclusion in the systematic review.

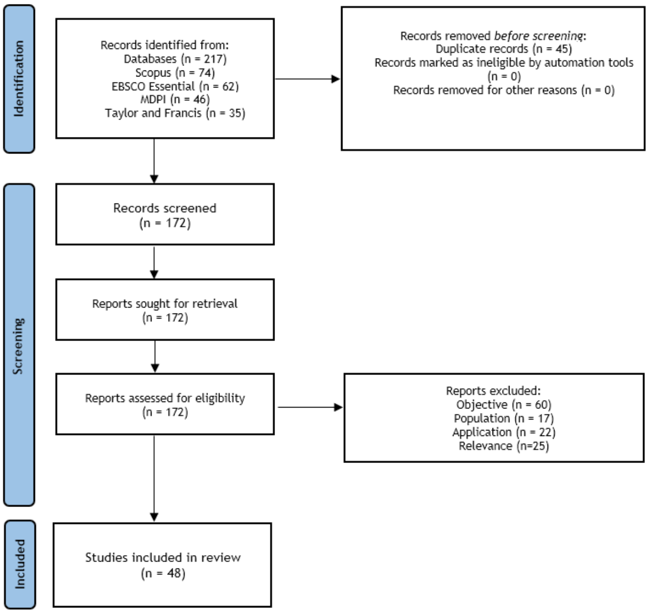

Figure 2: PRISMA flowchart used to determine the number of papers used in the literature review

The final literature search was located in the databases of Scopus, EBSCO Essential, MDPI, and Taylor and Francis, and the analysis was based on the bibliometrics of the literature.

A bibliographic search is frequently used in the so-called state-of-the-art of researchers who seek the theoretical foundations of their study variables. Below is presented the database matrix built with the existing literature (Table 2).

4. RESULTS

Table 2: Search mechanisms for obtaining information

Author	Journal	Year	Keywords	Location
A. Bytniewski	*Springer*	2020	Blockchain, blockchain application, government.	Poland
N. Bhagwan	*Journal of Energy in Southern Africa*	2022	I4.0 technology, energy sector, the IoT, real-time data, artificial intelligence, integration of human machines.	South Africa
Z. Dobrowolski	*Energies*	2021	Energy, risk, the IoT, big data, I4.0, supply chain and logistics.	Poland
S. Manna	*Inter Journal of Eng and Tech Innovation*	2023	Power peak point tracking, angle controller, and wind power.	India
C. Wang	*Global Energy Interconnection*	2022	Wind turbines, power modelling systems, and wind factory modelling.	China
S. Roy	*Energies*	2022	Electromagnetic induction, wind power, autonomous wireless sensors, and electronic force management.	Bangladesh
H. Teimourian	*Springer*	2022	Wind energy, the IoT, energy.	Turkey
S. Karad	*Springer*	2021	Wind power plants, integration of the IoT, and the internet of energy.	India
Y. Zou	*Materials*	2022	Nano triboelectric generators, wind power, distribution sensors, the IoT.	China
M. Liton	*CSEE - Journal of Power and Energy Sys*	2021	Asset management, condition monitoring, the IoT, wind energy and conversion systems.	Australia
L. Alhmoud	*Open Engineering*	2019	*The IoT, wind energy, wind speed and sensors.*	Brazil
M. Lanre	*International Journal of Energy Research*	2021	*Energy 4.0, smart energy & wind farm.*	China
N. Shabbir	*Computers, Materials & Continua*	2022	*Wind energy production, energy forecasting, and machine learning.*	Estonia
N. Jha	*Hindawi-Mathematical Problems in Eng*	2022	*Hybrid energy, solar and wind energy.*	India
H. Elahi	*Energies*	2020	*Energy harvesting, the IoT, batteries, solar, wind, and thermal energy.*	Italy
R. Raja	*IEEE Access*	2022	*Wind emulator, DC machine, FPGA controller, the IoT, Python, and web services.*	India
A. Paolo	*Mechanics & Industry*	2022	*Hydropower diagnostics, vibration monitoring, orbit identification, PCA ellipse adjustment.*	Italy
J. Sanz	*Prensas Universitárias de Zaragoza*	2016	*Renewable energy, hydropower plants, and hydropower.*	Spain
N. Yuniarti	*IJIM*	2021	*River flow, IoT, hydropower plant, and rural electrification.*	Indonesia
M. Akif	*Energies*	2022	*Machine learning, anomaly detection, hydropower plant, and normal behaviour model.*	Turkey
F. Sharif	*Plos One*	2021	Energy sector, hydroelectric station.	Bangladesh
O. Sheerifdeen	*Journal of Renewable Energy and Sustainable Dev (RESD)*	2022	*Electricity, GIS, rural electrification, mini-hydro potential.*	Nigeria
M. Wenfeng	*Earth and Environmental Science*	2021	*Hydraulic intelligence, the IoT.*	China
R. Singh	*Sensors*	2022	*Blockchain, energy trading, energy grid, the IoT, renewable energy, machine learning.*	USA
S. Mohammed	*Renewable and Sustainable Energy Reviews*	2018	*Solar energy, solar water pumping, Concentrated solar thermal, Stirling engine, irrigation.*	Sub-Saharan Africa
L. Chitra	*International Journal of Photoenergy*	2022	*The IoT, solar energy, monitoring model.*	India
A. Rajendra	*International Journal of Photoenergy*	2021	*TBSS solar distiller & CBSS distiller.*	India

Author	Journal	Year	Keywords	Location
V. Anantha	*International Journal of Photoenergy*	2022	*Solar energy, the IoT, microgrid control.*	India
P. Mohan	*Sensors*	2022	*Subsea sensor networks, energy efficiency, metaheuristics, network life, communication, routing.*	India
S. Mukase	*World electric Vehicle Journal*	2022	*Power consumption, ephemeral algorithm, wireless power transfer, periodic charging, renewable sensor wireless networks.*	China
S. Kwak	*Sensors*	2022	*Solar power generation, energy trading, auction theory, testbed, media study, the IoT, blockchain, forced learning.*	Korea
A. Paez	*Sensors*	2022	*Energy harvesting, the IoT, physiological sensors, solar energy, wireless communication, wireless sensor network.*	Madrid (Spain)
V. Ramamurthhi	*IETE Journal of Research*	2020	*Architecture, clarity index, cryptography, genetic algorithm, tilt angle, the IoT, remote monitoring, solar power, solar panel.*	India
F. Ali	*Designs*	2022	*The IoT, switchboard, renewable energy.*	South region of India
S. Correia	*Advance Science*	2022	*The IoT, solar concentrator, own power, solar power, temperature sensor, zero energy buildings.*	Portugal
H. Zhou	*Wireless Communications and Mobile Computing*	2021	*The IoT, solar energy.*	Shaoxing (China)
D. Patel	*Springer*	2022	*Solar radiation, solar energy, fuzzy logic.*	India
S. Lanka	*AIP*	2020	*Solar energy, the IoT, global warming, electricity, solar panels, temperature, lightning detection, human movement.*	India
C. Toma	*Informática econômica*	2018	*The IoT, cloud service, API, cyber security, crypto security.*	Bucharest
R. Aliguliyev	*International Journal of Hyperconnectivity and the IoT*	2020	*Big data, cloud computing, data mining, the IoT, petroleum industry.*	Azerbaiyán (Socar)
I.Olaizola	*Sensors*	2022	*Refinery 4.0, oil & gas, artificial intelligence, I4.0.*	Spain
C. Gooneratne	*IEEE Engineering*	2020	*Management of scientists and engineers, organisational culture, R+D+i project management, fourth industrial revolution, digital transformation.*	Japan
A. Allahloh	*Wireless communications and mobile computing*	2022	*The IoT, petroleum, pump efficiency, production.*	Saudi Arabia
U. Farooq	*Journal of sensors*	2021	*Routing, wireless sensors, subsea.*	Saudi Arabia
K. Wang	*Mobile Information Systems*	2022	*Cloud computing, the IoT, oil & gas, surveillance systems.*	China
A. Bašová	*Sociálno-ekonomická revue*	2020	*Digitalisation, marketing strategies, energy models, I4.0.*	Slovak Republic
S. Reed	*Ciencia*	2010	*Energy, water, electricity, electric power demand.*	México
IRENA	*International Renewable Energy Agencia: Abu Dhabi*	2022	*Energy sources, solar energy, bioenergy, geothermal energy, wind energy.*	Middle East

4.1. Analysis of information

The MAXQDA software in its 2022 version was used as part of the qualitative analysis of the data, using the word cloud tool, which has the function of structuring a set of words from text in the form of a visual design and hierarchically organising the terms that are presented most frequently. Figure 3 shows the most frequently used keywords in the search for information from the scientific literature related to this work. The use of the word cloud made it possible to identify and discern which words were most closely related to the research topic. According to [58], word frequency can be regarded as a valid measure of the relative importance of words in documents.

Figure 3: Keywords used in the data cloud

Publications related to IoT as a component of Industry 4.0 and its application in the energy sector have had annual participations, identifying 48 relevant products for this study, as illustrated in Figure 4.

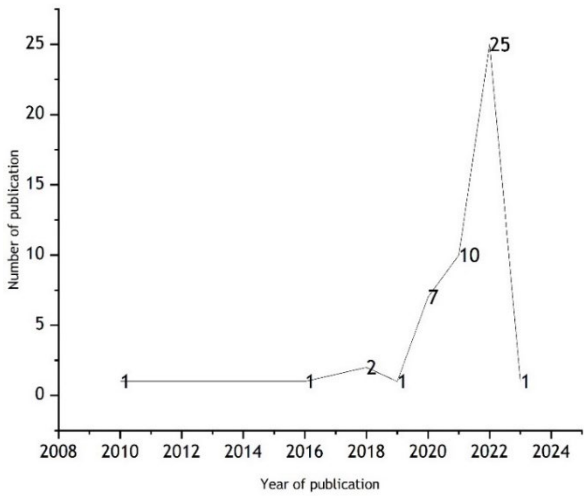

Figure 4: Number of publications on I4.0 and its application with the energy sector

5. CONCLUSIONS

The literature that was analysed indicated that wind energy has benefited from the application of controller technology with the ability to regulate the power that is generated. The IoT, as an integral element of I4.0, has made it possible to create new systems that are capable of the real-time environmental monitoring of humidity and temperature, which the information being sent to smartphones for analysis; a maximum efficiency of 73% has been achieved in some cases. IoT systems that are located in the cloud and big data present an approach to wind energy as a source of renewable energy.

Large hydroelectric power plants harness the power of water to obtain greater amounts of electrical energy. The potential of this resource is 95%: it converts the potential energy of water into a source of kinetic energy by passing the flow of water through clean-energy-generating turbines.

Solar technology that uses solar panels to convert energy, with the support of the IoT in control models, can manage energy consumption. There has been an increase in the use of new platforms to promote solar energy trading as a clean energy approach. With the application of the IoT and artificial intelligence, it would be possible to generate precise amounts of solar energy.

The fossil energy industry is highly complex; the handling of O&G requires specialised equipment. The use of technology in the extraction and refining process has been increased to reduce production costs, ensure productivity, and improve the product.

The IoT is a component of I4.0 that allows the generation of technology that helps to control processes in real time and that minimises and controls errors. New technology systems learn how to solve or prevent disasters in organisations in the energy sector through artificial intelligence.

The IoT has benefitted the energy sector, as indicated by the 48 reviewed documents. The year with the highest production of articles was 2022, with 25 titles on the researched topic; the year with the second-highest production was 2021, with 10 publications. The keywords of the documents indicated a concurrence in the data cloud with the terms 'energy', 'IoT', and 'solar energy', which showed the relevance of the documents that were investigated. The literature that was analysed revealed studies that investigated this relationship, identifying that the IoT has benefits for the energy sector.

The use of advanced I4.0 technologies, such as the IoT, AI, and data analytics, enables a smarter and more efficient management of various energy sources. In solar and wind energy, these technologies facilitate integration into electricity grids and the forecasting of energy production. In hydropower, those technologies optimise the operation of plants and the management of water resources. As for fossil energy, they improve operational efficiency and reduce emissions through advanced monitoring and control.

In the future, I4.0 should bring about a profound transformation in the energy sector, promoting a more sustainable future. By improving the efficiency and management of all energy sources, their environmental impact will be minimised and the foundation for a cleaner and more resilient energy economy will be laid. In short, both I4.0 and the future Industry 5.0 will not only optimise the operation and management of different energy sources, but will also play a key role in the transition towards a more sustainable energy system that is adaptable to future needs.

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