ISBN 978-989-9121-31-7
2nd International Conference on Challenges in Engineering, Medical, Economics and Education: Research & Solutions (CEMEERS-23b)
Istanbul (Turkiye) Nov. 23-24, 2023

Recent Energy Systems opportunities for Information Science and Technology: Blockchain, IoT and Smart Grids

Nuno Domingues[1,3], Luís B Elvas[2], Ana L Martins[3], Joao C Ferreira[2,3]

[1]Instituto Politécnico de Lisboa/ Instituto Superior de Engenharia de Lisboa, 1959-007 Lisbon, Portugal, nndomingues@gmail.com
[2]Instituto Universitário de Lisboa (ISCTE-IUL), ISTAR, 1649-026 Lisbon, Portugal; Luis.Elvas@iscte-iul.pt
[3]Inov Inesc Inovação—Instituto de Novas Tecnologias, 1000-029 Lisbon, Portugal
[4]Business Research Unit (BRU-IUL), Instituto Universitário de Lisboa (ISCTE-IUL), 1649-026 Lisbon, Portugal, almartins@iscte-iul.pt

Abstract: *Blockchain, IoT, and smart grids have the potential to revolutionize the energy industry by improving the efficiency, security and transparency of energy transactions. This is more evident when considering types of energy. However, there are several challenges that need to be addressed before these technologies can be fully implemented in the energy sector.*

Blockchain, IoT, and smart grids offer notable business possibilities for companies in the energy sector. This paper focus on scalability (current blockchain technology is not able to handle the high number of transactions that are required for large-scale energy systems), the integration of IoT and smart grids are data privacy, data anonymization and cybersecurity (with the large amount of data generated by IoT devices, ensuring that this data is protected from cyber-attacks, negligent actions and unauthorized access is essential). Also, the integration of IoT and smart grids requires the development of new communication protocols and standards to ensure that the data can be securely and efficiently transmitted. A third set of challenges is related to standardization, as the integration of these technologies also requires the development of common standards and protocols to ensure interoperability between different devices, systems, and networks.

Based on the present study it is possible to understand that several works and studies have been done raising the problems, but the solutions are still scarce and not tailor made. In general, even with the many possible advantages of using blockchain, IoT, and smart grids in the energy sector, there is also an indefinite number of challenges that need to be considered for these technologies to be fully used. Development and investigation in these areas are ongoing and it is substantial to keep track of the current developments. In conclusion, although the energy sector offers numerous prospective business prospects, it comes with its share of obstacles that demand attention to unlock the full potential of these technologies. Companies must prioritize staying afloat with the most recent advancements and trends in the industry and commit to research and development as a means of maintaining competitiveness.

Keywords: *Blockchain; IoT, Smart Grids, Energy*

1. Introduction

Energy Market liberalization, greater competition into electricity and gas markets, energy price subject to privatization, new players on consumption, production and consumption+production, renewables, electric mobility, intermittency and storage requires new system managing and planning. Old methods (such as SCADA, Loss of Power analyses, regression techniques, continuity of supply strategy and daily/ weekly/ annually profiles) are no longer valid under the new challenges. Moreover, the amount of data produced by consumers, producers, prosumers, brokers, communities and regulators allied with the need to control the energy grids at short term, create an opportunity for Information Science and Technology, namely Blockchain, IoT and Smart Grids. Integrating these devices offer a reliable solution by operating controllable and uncontrollable production loads, thus improving the efficiency, security and transparency of energy systems. Thereby, Blockchain, IoT, and smart grids are technologies that have the potential to revolutionize the energy sector.

Nevertheless, to use these technologies to their fullest, there are some challenges that need to be mentioned.Blockchain technology can be used to generate decentralized energy systems that enable peer-to-peer energy trading and allows the inclusion of renewable energy sources. Despite that, challenges related to scalability, regulatory compliance, and the integration of existing energy systems are still present. IoT technology can be utilized to enhance the monitoring, control, and automation of energy systems. Anyhow, challenges related to security, data privacy, and the integration of existing energy systems still endure. Smart grids can be used to embellish the efficiency, reliability, and flexibility of energy systems.

Nonetheless, challenges related to cybersecurity, data privacy, and the integration of renewable energy sources still stand. Achieving interoperability, by integrating all these technologies together, and obtaining communication between different systems is still a challenge that needs to be considered. To guarantee that these technologies are used in a protected and out-of-danger manner, regulatory frameworks and policies need to be put in place. Furthermore, they need to be associated with energy systems already in existence.

To unlock the full potential of these technologies, some challenges must be addressed. Blockchain technology can be used to generate decentralized energy systems that enable peer-to-peer energy trading and allows the inclusion of renewable energy sources. Despite that, challenges related to scalability, regulatory compliance, and the integration of existing energy systems are still present. IoT technology can be utilized to enhance the monitoring, control, and automation of energy systems. Anyhow, challenges related to security, data privacy, and the integration of existing energy systems still endure. Smart grids can be used to embellish the efficiency, reliability, and flexibility of energy systems.

2. Materials and Methods

To investigate the practices of the interseption of Blockchain, IoT and smart Grids contexts, we carried out a scoping study using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) approach [1]. We created and provided a detailed description of the suggested framework based on the findings of the current literature review. The research was carried out through June 2023 using the databases Scopus and the Web of Science Core Collection (WoSCC), and all the findings required to be from English-language publications that were published between 2017 and 2022. Title, author, year, journal, topic area, keywords, and abstract were all included in the data, which was managed and maintained via Zotero and Microsoft Excel. Based on the results shown above, a qualitative evaluation was done for data synthesis and analysis. Both the databases Scopus and WoS were thoroughly searched for published articles associated with the field of “Blockchain”, “IoT” and “Smart Grids” to indicate the current status and future challenges. All 46 studies included in the review were selected using the specific criteria mentioned above. After that, we divided the papers into several areas.

There have been many studies and research work focused on the challenges and opportunities of integrating Blockchain, IoT and smart grids in the energy sector. Here are some major works in this area:

"Blockchain for Internet of Energy management: Review, solutions, and challenges" by Arzoo Miglani, Neeraj Kumar, Vinay Chamola, and Sherali Zeadally [2], is a research paper that explores the use of Blockchain in the energy sector for Internet of Energy (IoE) management. The paper provides an overview of the existing literature on the integration of Blockchain and IoE and reviews various solutions that have been proposed to address the challenges associated with this integration.

R. Huo et al.'s paper "A Comprehensive Survey on Blockchain in Industrial Internet of Things: Motivations, Research Progresses, and Future Challenges" [3], provides a comprehensive overview of the integration of Blockchain and the Industrial Internet of Things (IIoT). The paper discusses the motivations for using Blockchain in the IIoT, including improved security, transparency, and decentralization. It also highlights the progress made in this field and presents the latest research advancements. The paper concludes by discussing the main challenges and future directions for research on blockchain in the IIoT, such as scalability, energy consumption and standardization. The authors aim to provide a comprehensive picture of the current state of research in this field and help to inform future work in this area.

"Blockchain Technologies for the Internet of Things: Research Issues and Challenges" from M. A. Ferrag et al. [4], provides an overview of the current state of research on the integration of Blockchain and IoT technologies. They explore the potential benefits of this integration, such as increased security and privacy, and examine the key research issues and challenges that must be addressed to achieve these benefits. The authors also provide a comprehensive overview of the current state of research in this area and outline the future directions for research and development in this field.

The paper "Unification of Blockchain and Internet of Things (BIoT): requirements, working model, challenges and future directions" by Bhushan, Sahoo, Sinha, et al. [5], provides an overview of the integration of

Blockchain and Internet of Things (IoT). The authors discuss the requirements, working model, and potential benefits of combining these technologies, such as increased security, transparency, and reliability. They also explore the challenges of integrating Blockchain and IoT, including scalability, energy consumption and data privacy. The authors present potential solutions to these challenges and provide insights into the future direction of this field.

"Blockchain Technology Toward Green IoT: Opportunities and Challenges" by P. K. Sharma, N. Kumar and J. H. Park [6], explores the integration of Blockchain technology and the Internet of Things (IoT) in the context of the green energy sector. The authors examine the potential benefits of this integration, such as improved energy efficiency and security, and increased transparency. They also discuss the challenges faced in implementing Blockchain in the green energy sector, including regulatory barriers, scalability, and energy consumption. The paper provides a comprehensive overview of the opportunities and challenges of using Blockchain technology in the IoT for green energy management.

"Blockchain for Internet of Energy Management: Review, Solutions, and Challenges" by Arzoo Miglani et. al [7], provides an overview of the use of Blockchain in the energy sector with a focus on the Internet of Energy (IoE). The paper reviews the current state of research on the integration of Blockchain and IoE and discusses the various benefits of this integration, such as increased transparency, improved energy efficiency, and enhanced security. Additionally, the paper highlights the main challenges associated with the integration of Blockchain and IoE, such as data privacy, interoperability, and scalability. The authors provide insights into the various solutions proposed to address these challenges and discuss future research directions in this field.

The paper "When Blockchain Meets Smart Grids: A Comprehensive Survey" by Yihao Guo, Zhiguo Wan, and Xiuzhen Cheng [8], provides an overview of the integration of Blockchain and smart grids. The authors review the various applications of Blockchain in the energy sector, such as peer-to-peer energy trading, demand response management and renewable energy integration. The authors also discuss the challenges and solutions of integrating Blockchain into smart grids, including scalability, interoperability, privacy and security. They conclude by highlighting the future directions for research in this area and the potential for further growth and development.

Jéssica Alice A. Silva, Juan Camilo López, Cindy Paola Guzman, Nataly Bañol Arias, Marcos J. Rider, Luiz C.P. da Silva, An IoT-based energy management system for AC microgrids with grid and security constraints, Applied Energy, Volume 337, 2023, 120904, ISSN 0306-2619. [9] This study introduces an Internet-of-Things (IoT) powered energy management system (EMS) designed for the efficient operation of unbalanced three-phase AC microgrids. The system is built upon a software framework structured around microservices, which includes a stochastic economic dispatch optimizer (EDO), a database, a web-based graphical user interface (GUI), and an application programming interface (API). The EDO component employs a mixed-integer linear programming (MILP) model to ensure the optimal scheduling of distributed energy resources (DERs) within the microgrid on a day-ahead basis, while taking into consideration grid-related limitations such as voltage, current, and power constraints. Furthermore, this optimization module incorporates security parameters to account for unforeseen islanded operation scenarios and accommodates stochastic variations in local demand and renewable energy generation.

"Blockchain, AI and Smart Grids: The Three Musketeers to a Decentralized EV Charging Infrastructure" by H. ElHusseini et al. [10] discuss the potential benefits of integrating Blockchain, artificial intelligence (AI), and smart grids to create a decentralized electric vehicle (EV) charging infrastructure. The authors first provide an overview of Blockchain and its applications, as well as an overview of AI and its applications in smart grids. They then describe how these two technologies can be combined with smart grids to create a decentralized EV charging infrastructure. The authors argue that the integration of Blockchain, AI and smart grids can provide numerous benefits for the EV charging infrastructure. For example, it can increase security, reduce costs and improve efficiency. The authors also highlight some challenges that need to be addressed in order to realize the full potential of this integration, such as scalability and regulatory issues.

In [11], HEMS-IoT (Home Energy Management System-Internet of Things) is a smart home system that utilizes big data and machine learning to optimize energy consumption and save energy. The main advantages are:

- Big Data: HEMS-IoT uses big data to collect, store and analyze large amounts of data from various sources such as energy consumption, weather and occupancy. This data can be used to create detailed energy consumption profiles, which can be used to optimize energy consumption.
- Machine Learning: HEMS-IoT uses machine learning algorithms to analyze the data collected from various sources and make predictions about energy consumption patterns. This can help to identify patterns and trends in energy consumption and make predictions about future energy consumption.

- Smart Home Automation: HEMS-IoT uses smart home automation to control and optimize energy consumption in the home. It can be used to control lighting, heating, cooling and appliances based on the data collected and analyzed and can also be integrated with other smart home systems such as security and home entertainment systems.
- Energy Saving: by using big data and machine learning, HEMS-IoT can optimize energy consumption in the home and save energy. This can help to reduce energy costs and reduce the environmental impact of energy consumption.
- Remote monitoring: HEMS-IoT can be accessed remotely, allowing homeowners to monitor and control energy consumption from anywhere. This can help to improve the convenience and ease of use of the system.

HEMS-IoT is a concept that is still being developed, and there is still more research needed to be done to fully realize its potential.

In [12], the Internet of Things (IoT) has the potential to revolutionize the way smart grids operate by enabling real time monitoring and control of energy systems. However, the use of IoT in smart grid communication requires the implementation of efficient and reliable communication protocols. We have a review of major works on:

- Zigbee: Zigbee is a low-power and low-data rate wireless protocol that is often used in smart grid communication. It is designed for use in low-power devices and is well-suited for monitoring and control applications.
- Z-Wave: Z-Wave is another low-power wireless protocol that is often used in smart grid communication. It is designed for use in home automation and is well-suited for controlling devices and appliances.
- 6LoWPAN: 6LoWPAN is a wireless protocol that is designed for use in low-power and low-data rate IoT devices. It is often used in smart grid communication for monitoring and control applications.
- WirelessHART: WirelessHART is a wireless protocol that is designed for use in industrial automation and control systems. It is often used in smart grid communication for monitoring and control applications in power plants and substations.
- MQTT: MQTT is a lightweight messaging protocol that is designed for use in IoT devices. It is often used in smart grid communication for data collection and analysis.
- LwM2M: Lightweight Machine to Machine (LwM2M) is a device management protocol for IoT devices. It is designed for low-power and low-bandwidth devices, and it is used for device management, security and data collection.

In [13], the integration of DERs, AI, IoT, and Blockchain technology can significantly enhance the capabilities of smart grids and pave the way for a more sustainable and efficient energy future. Distributed energy resources (DERs) such as rooftop solar panels, wind turbines and electric vehicles can be integrated into smart grids to increase the use of renewable energy and to improve the efficiency and reliability of energy systems. The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Blockchain technology can further enhance the capabilities of smart grids and DERs:

- AI: AI can be used to optimize the operation and control of DERs in real-time, by predicting energy demand, forecasting renewable energy production and enabling dynamic pricing.
- IoT: IoT can be used to monitor and control DERs and smart grid systems, by connecting devices and collecting data on energy consumption and production. IoT can also be used to improve grid security and enable the integration of renewable energy resources.
- Blockchain: Blockchain can be used to create a secure and transparent platform for the management of energy data and transactions. It can also be used to enable peer-to-peer energy trading, allowing for the buying and selling of energy among individuals and small businesses, and to improve the security of IoT devices by providing secure and transparent record-keeping of energy data.
- Virtual Power Plant: by integrating all the technologies above, it is possible to create a virtual power plant where a group of distributed energy resources can be managed and operated as one entity, optimizing the energy production and consumption and providing flexibility to the grid.
- Microgrid: IoT, AI and Blockchain can also be used to create microgrids, which are small-scale energy systems that can operate independently of the main grid. This allows for the use of renewable energy resources in remote and off-grid areas, and to ensure the resilience and security of the energy supply.

In [14], demand response is a key technique in the demand management for energy in smart grids. The residential appliance scheduling problem is a specific type of demand response problem that can be optimized using various techniques, such as mathematical programming, heuristics, metaheuristics, machine learning and others. Demand response (DR) is a technique used to manage the demand for energy in smart grids. The goal of demand response is to reduce the peak demand for energy, which can help to improve the efficiency and reliability of the grid. The residential appliance scheduling problem is a specific type of demand response problem that involves scheduling the operation of appliances in a household to reduce energy consumption during peak demand periods. Major working areas are:

- Optimization techniques: there are various optimization techniques that can be used to solve the residential appliance scheduling problem. These include mathematical programming, heuristics and metaheuristics.
- Model Predictive Control (MPC): MPC is a technique that uses mathematical models to predict future energy consumption and optimize the operation of appliances.
- Stochastic programming: stochastic programming is a technique that can be used to optimize the operation of appliances in the presence of uncertainty in energy consumption.
- Particle Swarm Optimization (PSO): PSO is a metaheuristic optimization technique that can be used to find the optimal solution to the residential appliance scheduling problem.
- Genetic Algorithm (GA): GA is a heuristic optimization technique that can be used to find the optimal solution to the residential appliance scheduling problem.
- Machine Learning: machine learning algorithms can be used to analyze historical energy consumption data and predict future energy consumption. This can help to optimize the residential appliance scheduling problem.

In [15], an IoT-based digital twin for energy cyber-physical systems can be used to improve the efficiency and reliability of energy systems by simulating and optimizing their performance. The design and implementation of an IoT-based digital twin involves several steps, such as system modeling, IoT data collection, cloud computing, machine learning, cybersecurity and integration with the physical energy system. An IoT-based digital twin for energy cyber-physical systems is a virtual representation of a physical energy system that can be used to simulate and optimize the performance of the system. The design and implementation of an IoT-based digital twin for energy cyber-physical systems involves several key steps:

- System modeling: the first step in designing an IoT-based digital twin is to create a mathematical model of the physical energy system. This model should include data on the system's components, their interactions, and the system's behavior under different conditions.
- IoT data collection: IoT devices such as sensors, actuators and controllers are used to collect data on the physical energy system in real-time. This data is then used to update the digital twin model and improve its accuracy.
- Cloud computing: the digital twin is usually hosted on the cloud, which allows for easy access and storage of large amounts of data, and to run the computational-intensive tasks needed for the simulation and optimization.
- Machine Learning: machine learning algorithms can be used to analyze the data collected from the physical energy system and to make predictions about the system's behavior. This can be used to optimize the performance of the system and identify potential issues before they take place.
- Cybersecurity: it is significant to implement cybersecurity measures in order to protect the digital twin and the data collected from the physical energy system from cyberattacks.
- Integration: the digital twin should be integrated with the physical energy system, which allows for the simulation and optimization of the system to be translated into real-world actions.

In [16], it is mentioned how IoT and machine learning can be used to improve waste management and predict air pollutants. IoT sensors can be placed in waste bins to monitor their fill level and schedule pickups when needed. Machine learning algorithms can analyze the data from these sensors to optimize waste collection routes and reduce the number of unnecessary pickups. Additionally, IoT sensors can be used to monitor air quality and predict pollutants. Machine learning algorithms can analyze this data to identify patterns and predict when air pollution levels may be high. This information can be used to take proactive measures to reduce pollutants, such as shutting down certain factories or limiting the use of vehicles in certain areas.

In [17], the Economic Model Predictive Control (EMPC) is mentioned as a method for controlling energy dispatch in smart grids by balancing the cost of energy production with the demand for energy. A robust EMPC system can take into account uncertainty in the demand for energy and make decisions that minimize the cost of energy production, while ensuring that the demand for energy is met. One approach to achieving robustness in EMPC systems is to use a zonotope, which is a mathematical representation of a set of uncertain variables. By using a zonotope, the EMPC system can take into account multiple possible scenarios for the demand for energy and make decisions that are robust to these uncertainties. Additionally, a local feedback controller can be used to improve the performance of the EMPC system. This type of controller can adjust the energy dispatch in real-time based on local measurements of the demand for energy.

Overall, the combination of a zonotope and local feedback controller can improve the robustness of the EMPC system and better handle demand uncertainty in smart grids, leading to a more efficient and cost-effective energy dispatch.

In [18], a study is made to identify potential in the innovation ecosystem focusing on a text mining technique and similarity-based analysis. The purpose of this study was sensing innovation opportunities through intelligent trends and interaction analysis in science, technology and business (S-T-B) fields in the value chain of smart grids, which is the research target area. Topic modeling and cosine similarity measurements were carried out using scientific papers, patent and business publication data corresponding to the S-T-B ecosystem. Through multi-dimensional data sources corresponding to the S-T-B fields, the evolutionary path of the smart grid value chain and its potential as a strategic tool for future innovative challenges were identified.

In [19], a review conducts an in-depth review of the application of formal methods in the context of smart contract specification and verification. Formal methods encompass mathematical techniques used to model, design, and rigorously test both software and hardware systems, ensuring their correctness and reliability.

In [20], this paper presents an innovative approach to the formal verification of smart contracts, utilizing models based on user behaviors and blockchain actions. Smart contracts, essential components of blockchain technology, have gained widespread use in various industries, offering automated and trustless execution of agreements. Ensuring the correctness and reliability of these contracts is crucial to avoid financial losses and maintain the integrity of blockchain systems.

Table 1 shows the papers' systematization among major topic areas.

	Application of Bck IoT	Survey Bck and IoT application in Bck	Energy Savings -DER	Eenrgy Trading	Privacy and Security	EV integration	Monitor and control	Simulation towards savings	AI application	Energy Sharing	Smart Home	Data Interoperability	Bck application / smart contract	Tokenization of Energy
1	x	x												
2	x	x												
3		x												
4			x											
5	x	x												
6	x													
7														
8	x		x											
9			x											
10						x								
11			x					x						
12							x							
13			x											
14			x											
15								x						
16	x													
17				x										
18													x	
19														x
20														x

3. Conclusions

Despite the fact that power grids have been planned, managed and run for a long time with centralized grids, which have large scale power plants away from the consumption clients, in recent years, there are occurring significant changes worldwide, due to the decentralized energy resources growth, the development of energy storage systems, the increased use of electric vehicles, new energy market agents and the investment in intermittent/ uncontrollable forms of primary energy. This is an opportunity for the integration of Blockchain technology, IoT and smart grids in the energy sector. However, this is currently in the early stages of implementation. Some examples of current projects include: 1) Blockchain-based energy trading: several pilot projects are underway to test the use of Blockchain technology for peer-to-peer energy trading between consumers and producers; 2) IoT-enabled grid management: IoT devices such as smart meters and sensors are being used to improve the efficiency and reliability of grid operations; and 3) Blockchain-enabled energy certification: Blockchain technology is being used to track and verify the origin and authenticity of renewable energy certificates.

The synergy between blockchain and IoT can revolutionize the energy sector by enabling real-time monitoring, efficient energy distribution, decentralized energy trading and improved grid stability. These technologies empower individuals and organizations to make informed decisions about their energy usage, reduce waste, and promote the adoption of renewable energy sources, ultimately contributing to energy conservation and sustainability.

One of the biggest benefits of the IoT is its ability to reach increasingly remote places via smart devices and edge computing. Allied with techniques, the data was acquired as potential when well managed. The main advantages of Blockchain are security, transparency, free access and decentralization. This technology offers a safer way to register and store data, as it is encrypted in a block added to the network. Intelligent energy management improves the way people live, work and entertain themselves. Currently, several technologies that seek to increase the autonomy of IoT systems are already available on the market. In the era of big data and IoT, digital connectivity exists throughout manufacturing, the power grid, buildings, healthcare facilities, transportation and in the home. Smart energy solutions that collect data, learn and provide actionable insights to optimize energy usage and continuity are innovating. However, with the exponential rise in the number of devices, managing and delivering, the careful handling of the data still poses a major challenge to overcome.

Raw data has limited value, which means data science has a very important role. Turning this data into actionable information helps lower costs, drives efficiency, aids decision making and maximizes uptime.

In the future, it is expected that the integration of Blockchain technology, IoT and smart grids will continue to gain momentum, with more projects and pilot schemes being started. It is also expected that more standardization and regulatory frameworks will be put in place to facilitate the integration and scaling of these technologies, which could be used to create more decentralized and autonomous energy systems, with consumers and small-scale producers being able to participate in the energy market and manage their own energy consumption. Additionally, the implementation of these technologies could lead to improved energy efficiency, increased transparency and reduced costs.

Acknowledgments: This work was supported by the Fundação para a Ciência e Tecnologia under Grant [UIDB/00315/2020]; and by the project "BLOCKCHAIN.PT (RE-C05-i01.01 – Agendas/Alianças Mobilizadoras para a Reindustrialização, Plano de Recuperação e Resiliência de Portugal na sua componente 5 – Capitalização e Inovação Empresarial e com o Regulamento do Sistema de Incentivos "Agendas para a Inovação Empresarial", aprovado pela Portaria N.° 43-A/2022 de 19 de janeiro de 2022).

4. References

[1] H. -N. Dai, Z. Zheng and Y. Zhang, "Blockchain for Internet of Things: A Survey," in IEEE Internet of Things Journal, vol. 6, no. 5, pp. 8076-8094, Oct. 2019, doi: 10.1109/JIOT.2019.2920987. https://doi.org/10.1109/JIOT.2019.2920987

[2] Arzoo Miglani, Neeraj Kumar, Vinay Chamola, Sherali Zeadally, Blockchain for Internet of Energy management: Review, solutions, and challenges. Computer Communications, Volume 151, 2020, Pages 395-418, ISSN 0140-3664, https://doi.org/10.1016/j.comcom.2020.01.014.

[3] R. Huo et al., "A Comprehensive Survey on Blockchain in Industrial Internet of Things: Motivations, Research Progresses, and Future Challenges," in IEEE Communications Surveys & Tutorials, vol. 24, no. 1, pp. 88-122, Firstquarter 2022, doi: 10.1109/COMST.2022.3141490.

[4] M. A. Ferrag, M. Derdour, M. Mukherjee, A. Derhab, L. Maglaras and H. Janicke, "Blockchain Technologies for the Internet of Things: Research Issues and Challenges," in IEEE Internet of Things Journal, vol. 6, no. 2, pp. 2188-2204, April 2019, doi: 10.1109/JIOT.2018.2882794.

[5] Bhushan, B., Sahoo, C., Sinha, P. et al. Unification of Blockchain and Internet of Things (BIoT): requirements, working model, challenges and future directions. Wireless Netw 27, 55–90 (2021). https://doi.org/10.1007/s11276-020-02445-6

[6] P. K. Sharma, N. Kumar and J. H. Park, "Blockchain Technology Toward Green IoT: Opportunities and Challenges," in IEEE Network, vol. 34, no. 4, pp. 263-269, July/August 2020, doi: 10.1109/MNET.001.1900526
[7] Arezoo Hasankhani, Seyed Mehdi Hakimi, Mojtaba Bisheh-Niasar, Miadreza Shafie-khah, Hasan Asadolahi, Blockchain technology in the future smart grids: A comprehensive review and frameworks, International Journal of Electrical Power & Energy Systems, Volume 129, 2021, 106811, ISSN 0142-0615, https://doi.org/10.1016/j.ijepes.2021.106811.
[8] Yihao Guo, Zhiguo Wan, Xiuzhen Cheng, When blockchain meets smart grids: A comprehensive survey, High-Confidence Computing,Volume 2, Issue 2,2022,100059,ISSN 2667-2952,https://doi.org/10.1016/j.hcc.2022.100059.
[9] Jéssica Alice A. Silva, Juan Camilo López, Cindy Paola Guzman, Nataly Bañol Arias, Marcos J. Rider, Luiz C.P. da Silva, An IoT-based energy management system for AC microgrids with grid and security constraints, Applied Energy, Volume 337, 2023, 120904, ISSN 0306-2619 https://doi.org/10.1016/j.apenergy.2023.120904
[10] H. ElHusseini, C. Assi, B. Moussa, R. Attallah and A. Ghrayeb, "Blockchain, AI and Smart Grids: The Three Musketeers to a Decentralized EV Charging Infrastructure," in IEEE Internet of Things Magazine, vol. 3, no. 2, pp. 24-29, June 2020, doi: 10.1109/IOTM.0001.1900081.
[11] Machorro-Cano I, Alor-Hernández G, Paredes-Valverde MA, Rodríguez-Mazahua L, Sánchez-Cervantes JL, Olmedo-Aguirre JO. HEMS-IoT: A Big Data and Machine Learning-Based Smart Home System for Energy Saving. Energies. 2020; 13(5):1097. https://doi.org/10.3390/en13051097
[12] Tightiz L, Yang H. A Comprehensive Review on IoT Protocols' Features in Smart Grid Communication. Energies. 2020; 13(11):2762. https://doi.org/10.3390/en13112762
[13] Kumar NM, Chand AA, Malvoni M, Prasad KA, Mamun KA, Islam FR, Chopra SS. Distributed Energy Resources and the Application of AI, IoT, and Blockchain in Smart Grids. Energies. 2020; 13(21):5739. https://doi.org/10.3390/en13215739
[14] Shewale A, Mokhade A, Funde N, Bokde ND. An Overview of Demand Response in Smart Grid and Optimization Techniques for Efficient Residential Appliance Scheduling Problem. Energies. 2020; 13(16):4266. https://doi.org/10.3390/en13164266
[15] Saad A, Faddel S, Mohammed O. IoT-Based Digital Twin for Energy Cyber-Physical Systems: Design and Implementation. Energies. 2020; 13(18):4762. https://doi.org/10.3390/en13184762
[16] Hussain A, Draz U, Ali T, Tariq S, Irfan M, Glowacz A, Antonino Daviu JA, Yasin S, Rahman S. Waste Management and Prediction of Air Pollutants Using IoT and Machine Learning Approach. Energies. 2020; 13(15):3930. https://doi.org/10.3390/en13153930
[17] Nassourou M, Blesa J, Puig V. Robust Economic Model Predictive Control Based on a Zonotope and Local Feedback Controller for Energy Dispatch in Smart-Grids Considering Demand Uncertainty. Energies. 2020; 13(3):696. https://doi.org/10.3390/en13030696
[18] Kwang Hun Choi, Gyu Hyun Kwon, Strategies for sensing innovation opportunities in smart grids: In the perspective of interactive relationships between science, technology, and business, Technological Forecasting and Social Change, Volume 187, 2023, 122210, ISSN 0040-1625, https://doi.org/10.1016/j.techfore.2022.122210
[19] Y. Zuo, "Tokenizing Renewable Energy Certificates (RECs)—A Blockchain Approach for REC Issuance and Trading," in IEEE Access, vol. 10, pp. 134477-134490, 2022, doi: 10.1109/ACCESS.2022.3230937.
[20] M. F. Munoz, K. Zhang and F. Amara, "ZipZap: A Blockchain Solution for Local Energy Trading," 2022 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), Shanghai, China, 2022, pp. 1-5, doi: 10.1109/ICBC54727.2022.9805486.