Blockchain, IoT and Smart Grids Challenges for Energy Systems

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Abstract. In this work we performed a literature review on this emergent topic and resumed the major contribution of recent works on the topics of Blockchain, IoT, and smart grids and how they have the potential to revolutionize the energy industry by improving the efficiency, security and transparency of energy transactions. We have selected papers from journals based on provided keywords on the theme. One of the main challenges with using blockchain in energy is scalability. The current blockchain technology is not able to handle the high number of transactions that are required for large-scale energy systems. This is an active area of research and development, with various solutions proposed, such as sharding and off-chain transactions, to increase the scalability of blockchain. Other challenges with 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. Additionally, 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 challenge 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. Finally, regulatory and legal frameworks also play a critical role in the development and implementation of these technologies in the energy sector. As these technologies are still relatively new and given the energy widespread in many areas of society, the regulatory and legal frameworks are still being developed and may not be fully in place to support their widespread adoption. It is now crucial that a large number of actors from science, business, decision-making and civil society get involved in the energy transition, along with the energy experts and stakeholders. The Blockchain, IoT and Smart Grids are key.

Keywords: Blockchain; IoT, Smart Grids, Energy

1 Introduction

Energy systems are changing worldwide at different paces. New market models brought new agents that cope with existing ones. Producers, consumers, prosumers, marketers, for example, are very active in decentralized/ island energy grids. Various distributed energy agents' devices can be photovoltaic (PV) systems, wind generators, electric vehicle (EV) charge, small scale energy storage systems, energy communities, thermal generation increase foreseen new difficulties for monitoring and operating electrical distribution systems. Smart grids offer a reliable solution for integrating these devices and managing controllable and uncontrollable production loads. Blockchain, IoT, and smart grids are all technologies that have the potential to revolutionize the energy sector by improving the efficiency, security and transparency of energy systems. The Internet of Things (IoT) is a modern paradigm of computer networks with numerous applications in the industrial and technology sectors and enable advanced technologies mostly on the basis of advanced metering infrastructure and intelligent devices. In smart grids, IoT facilitates communication among agents, making it a useful tool for decision-making. Furthermore, the adoption of IoT in an EMS fosters the expansion of microgrids, as it allows to securely and remotely monitor and control them.

Nevertheless, to use these technologies to their fullest, there are some challenges that need to be mentioned:

- Blockchain: 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: 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: 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.
- Interoperability: Achieving interoperability, by integrating all these technologies together, and obtaining communication between different systems is still a challenge that needs to be considered.
- Regulation: 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.

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.

Blockchain, IoT, and smart grids offer notable business possibilities for companies in the energy sector. Nonetheless, some of the challenges that must be addressed to unlock the full potential of these technologies:

- Blockchain: 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: 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: 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.
- Interoperability: Businesses capable of offering answers to ensure communication that is interoperability and data exchange among diverse systems could gain a competitive edge.
- Regulation: Companies must adhere to current regulatory guidelines and policies, while also proactively preparing for forthcoming ones. This ensures the safe and secure utilization of these technologies while maintaining alignment with the established energy systems.

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.

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 show the current status and future challenges. All 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:

An extensive analysis of Blockchain technology's application in the Internet of Things (IoT) space is given by H.N. Dai et al [1]. A thorough discussion of the several kinds of Blockchain technologies—public, consortium, and private—as well as how well-suited they are for Internet of Things applications is given in this study. It also covers the primary uses of blockchain in the Internet of Things, such as energy management, supply chain management, and healthcare.

The incorporation of Blockchain technology with the Internet of Things (IoT) is the main emphasis of F. Golatowski et al. [2]. In addition to outlining the main obstacles and possibilities of this integration, this paper gives an overview of the present level of research on the integration of these two technologies. Additionally, it highlights a number of crucial issues that must be resolved, including the necessity for defined protocols and APIs, the scalability of Blockchain systems, and the integration of Blockchain with current IoT infrastructure.

A thorough examination of the integration of Blockchain with IoT technology is given by Zafar, S. et al. (2022) [3]. The authors look at the main obstacles to this prospective integration, such as interoperability, scalability, and regulatory restrictions, as well as the potential benefits, such as improved security, transparency and cost savings. The authors also suggest alternative solutions for these problems, emphasizing the value of a multidisciplinary strategy including a range of stakeholders. For researchers and practitioners interested in examining the combination of Blockchain and Internet of Things technology, the paper offers a useful resource.

Abed, S. et al. [4] classifies, presents, and assess solutions to use IoT conditions more successfully using current Blockchain technology. According to the report, most streamlined solutions deal with security or energy-related issues separately. Moreover, it emphasizes that a great deal of research is mainly theoretical and presents solutions in an Internet of Things environment based on blockchain without any real-world validation. Furthermore, the evaluation highlights how little study has been done to determine how energy efficient IoT hardware is. Furthermore, very few research have evaluated their approaches from the standpoint of devices with limited hardware. Because of this, the writers support the idea that every suggested solution must first be shown beneficial through practical application.

A thorough summary of the state of IoT technology in smart homes is given by Biljana L. Risteska Stojkoska and Kire V. Trivodaliev [5]. The authors go over the many uses and advantages of IoT in smart homes, such as increased security, increased comfort and convenience, and improved energy efficiency. The primary obstacles and constraints of IoT in smart homes are also examined, including problems with reliability and scalability, compatibility and interoperability, and data privacy and security. The authors analyze the ways in which these problems are currently being solved, such as the use of wireless sensor networks and cloud computing, and they make recommendations for future directions in this area of study.

Using a suitable hardware design, Samuel Karumba et al. [6] investigate the creation of a safe and energy-efficient Internet of Things system that integrates Blockchain technology. The report classifies, demonstrates, and assesses existing methods to improve IoT and Blockchain technology integration. The authors stress how critical it is to take hardware into account when assessing how well Blockchain-based IoT hardware implementation works. Moreover, they recommend that energy efficiency be given top priority in lightweight solutions while incorporating lightweight security measures.

The unique system proposed by S. Jannu et al. [7] addresses hot spot-related problems and increases the operational lifespan of Industrial Internet of Things (IIoT) networks in smart cities by effectively managing and utilizing energy. This system uses standard sensor nodes along with energy-harvesting nodes, and it is based on energy-conscious clustering and routing algorithms. The suggested system was used in extensive simulations that took different network topologies into account. Additionally, a comparison of some of the current algorithms is conducted because the results demonstrate a significant improvement in network lifespan when compared to current methods.

An in-depth examination of the application of Blockchain technology in smart grid systems can be found in Mollah et al.'s publication [8]. The writers go over how blockchain technology can be used in smart grids for energy trading, energy management, and energy storage, among other things. Additionally, they draw attention to the advantages of Blockchain technology for smart grids, including lower costs, better security, and increased transparency. The study also explores the field's future research directions and the possible influence of Blockchain technology on the development of smart grids.

Arezoo Hasankhani et al.'s study [9] offers a thorough analysis of how Blockchain technology will be applied in upcoming smart grids. The writers go over the advantages of adopting blockchain technology, like enhanced security, transparency, and dependability, as well as the drawbacks and restrictions, like energy consumption, scalability, and interoperability. The article also offers a number of frameworks, including transaction management, smart contracts, and consensus algorithms, for integrating Blockchain technology into smart grids. In their conclusion, the authors emphasize how Blockchain technology has the potential to revolutionize the energy sector and the necessity of more study and development to get past the obstacles that stand in the way of implementing Blockchain in smart grids.

Research on the use of Blockchain technology in smart grid systems for energy optimization was conducted by Harshal Patil et al. [10]. The writers examine how smart grids are currently operating and pinpoint the issues preventing them from being as secure and efficient as they could be. Subsequently, they offer an extensive analysis of how Blockchain technology is being incorporated into smart grid systems, emphasizing how this technology can enhance energy security and management. The authors also list the obstacles that must be removed, such as scalability and privacy issues, in order to completely realize the advantages of blockchain technology in smart grid systems. The paper ends with recommendations for further research in this area.

An overview of the use of Blockchain technology in smart grids for demand response management and safe energy trading is given by A. Kumari et al. [11]. The authors examine the advantages of blockchain technology, including security, immutability, and transparency, in the energy industry. They also look at the difficulties in scaling and integrating Blockchain with current systems when using smart grids. The authors propose and use simulation experiments to test a Blockchain-based system for demand response management and secure energy trading. The findings demonstrate that demand response management and energy trading can both be made more secure and efficient with the help of the suggested system. The authors draw the conclusion that more research is necessary to fully realize its potential, and that blockchain technology has the potential to completely transform the energy industry.

An overview of the application of Blockchain technology in the context of smart grid systems is given by A. S. Musleh et al. [12]. The authors present an overview of the advantages and difficulties of this technology in the energy sector and examine the body of literature and frameworks currently in use regarding Blockchain applications in smart grids. Additionally, they go over how Blockchain technology might be applied to smart grids for purposes like fraud detection, distributed energy resource management, and safe energy trading. The authors concluded that while there are still some technological and legal issues that need to be resolved, blockchain technology has a great deal of potential to enhance the security, effectiveness, and sustainability of smart grid systems.

The work of Bera et al. [13] focuses on creating an IoT-enabled smart grid system's Blockchain-based access control protocol. The authors emphasize the necessity of safe and decentralized access control systems in the smart grid, especially in light of the growing quantity of users and devices connecting to the system. The authors suggest a Blockchain-based protocol that secures device communication and enforces access control rules via smart contracts. Scalability, efficiency, and a high degree of security and privacy are all features of the suggested protocol. The authors also go over the difficulties and restrictions associated with putting the suggested protocol into practice and offer ideas for future research paths.

An overview of the application of Blockchain technology for cybersecurity in smart grids is given by P. Zhuang et al. [14]. The writers look at the state of blockchain technology in smart grids today, as well as the difficulties and potential paths ahead for this area. They offer a thorough analysis of the various ways that blockchain technology is applied in smart grids as well as the various kinds of blockchain technology that are employed. They also draw attention to the smart grid systems' security needs as well as privacy, trust, and scalability concerns. In closing, the authors outline some of the current frameworks and potential paths forward for creating cybersecurity solutions for smart grids based on blockchain technology.

Blockchain technology is suggested by C. Liu et al. [15] as a way to control EV participation in a smart grid platform. They contend that blockchain technology can be used to get around some of the shortcomings in the current EV management systems. The authors suggest an adaptable Blockchain-based EV participation program that lets EVs take part in smart grid management. The security and dependability of transactions between EVs and the smart grid are guaranteed by this system, which is built on a consensus algorithm.

In addition to introducing a thorough analysis of the de-development of Smart Grids in tandem with the adoption of Internet of Every-thing (IoE) systems, Mohammad Ghiasi et al. [16] also explores the essential components of IoE in relation to decarbonization. Furthermore, simulations and mathematical models are presented to evaluate the contribution of IoE to the decrease in carbon dioxide (CO2) emissions.

These papers demonstrate the importance of addressing the challenges and opportunities of integrating Blockchain, IoT and smart grids in the energy sector. Further research is needed to develop practical solutions to these challenges and to fully realize the benefits of this integration. Some more examples of important work on the topic are the following.

"Roaming service for electric vehicle (EV) charging using Blockchain-based digital identity," by Ferreira et al., [17]. This paper is based on an idea that makes use of digital identity and blockchain technology to make it simple and safe for electric vehicle owners to access charging stations across various networks. Given that Blockchain technology is being used to create a decentralized, transparent, and secure platform for storing EV charging transactions and digital identities, this has the potential to enhance the overall EV charging experience and increase the adoption of electric vehicles. This eliminates the need for multiple payment methods or contracts and enables EV owners to access charging stations across multiple networks and pay for charging services using a digital identity. Every owner of an EV receives a digital identity that they can use to access charging stations securely, which requires a secure and authenticated identity. As a result, RFID tags and physical cards are no longer necessary. EV owners are able to roam and access charging stations wherever they go because they can use the same digital identity on multiple networks. This improves the accessibility and convenience of EV charging and does away with the requirement for EV owners to register with multiple networks. Additionally, this strategy makes it possible for various payment methods and charging networks to work together, which makes it simpler for EV owners to pay for and access charging stations. In summary, digital identities and blockchain technology offer a transparent and safe platform for EV charging transactions while safeguarding the financial and personal data of EV owners.

IoT can be used in the energy sector to increase the sustainability, dependability, and efficiency of energy systems. An overview of how Blockchain technology and the Internet of Things (IoT) can be combined to create a safe, transparent, and decentralized platform for the exchange and management of energy data in the energy industry can be found in the work of Hossein Motlagh et al. [18]. This can facilitate the integration of renewable energy sources and enhance the sustainability, dependability, and efficiency of energy systems.

According to the article by Borowski [19], industry 4.0, blockchain, digital twins, and digitization can all be utilized to enhance the management procedures in businesses in the energy sector. To begin with, digitization is the process of transforming systems, data, and processes into digital format. Energy sector processes like energy trading and distribution can be made more transparent and efficient through digitization, and these processes can be stimulated and optimized with the help of a digital twin. A virtual copy of a real asset or procedure is called a digital twin. Furthermore, Industry 4.0, the fourth industrial revolution marked by the integration of cutting-edge technologies like IoT, AI, and cyber-physical systems in the energy sector, and Blockchain, a decentralized and transparent technology that can be used to create a secure and transparent platform for the management of energy data and transactions, can be used to create smart and connected energy systems, like smart grids. Additionally, it can enhance the security, efficiency, and transparency of the energy management procedures, enabling more sustainable and effective operations.

Elahi H. et al. [20], demonstrate that energy harvesting is a technique used to collect energy from the environment and convert it into usable electrical energy. This can be used to power IoT devices, making them self-sufficient and reducing the need for external power sources. The main benefits are several types of energy, such as solar energy harvesting, a renewable and sustainable energy in outdoor environments, which use solar panels to convert sunlight into electrical energy, that can be then used to power IoT devices. However, in kinetic energy harvesting, which uses motion to generate electrical energy, the environments where there is a lot of movement, such as factories or transportation systems would be ideal. However, thermal energy harvesting harnesses temperature variations to produce electrical energy, so it works best in areas with significant temperature variations, like industrial processes or buildings. Vibration energy harvesting also makes use of mechanical vibrations to produce electrical energy. IoT devices would benefit from this in places where there is a lot of vibration, like building sites or transit networks. Lastly, energy harvesting can be used to make Internet of Things devices self-sufficient and less dependent on external power sources. This can extend the devices' lifespan, lower maintenance costs, and boost system effectiveness.

An overview of smart grids, an upgraded form of the conventional electrical grid that uses digital technology to increase the sustainability, dependability, and efficiency of energy systems, is given by Alotaibi I. et al. [21]. Smart grids facilitate the integration of distributed energy resources, like rooftop solar panels and electric vehicles, and can also be used to integrate renewable energy sources. The primary focus of the discussion is advanced metering infrastructure (AMI), a crucial part of smart grids. It makes it possible to monitor and manage energy use in real time. As a result, utilities are able to increase grid reliability and better balance supply and demand for energy. Moreover, distributed energy resources like rooftop solar panels, wind turbines, and electric cars can be integrated into smart grids. This lessens reliance on fossil fuels and permits the use of renewable energy sources. Furthermore, energy storage devices like batteries can be integrated into smart grids to increase the grid's stability and dependability. This makes it possible to utilize renewable energy sources even when they aren't being produced, like at night or on overcast days. Furthermore, microgrids—small-scale energy systems that are independent of the main grid—can be developed using smart grids. This makes it possible to use renewable energy sources in isolated and off-grid locations. They also depend on sophisticated communication systems in order to provide real-time energy system monitoring and control. This covers the application of sophisticated metering infrastructure, communication networks, and sensors. In order to safeguard against cyberattacks and guarantee the dependability and stability of the grid, smart grids are dependent on sophisticated security systems.

Son Y-B et al. report on Peer-to-peer (P2P) energy trading in smart grids, which allows people and small businesses to trade energy with one another [22]. Blockchain technology can be used to create a safe and open platform for managing energy-related data and transactions. First off, functional encryption is a method that makes it possible to encrypt data so that only parties with permission can access it. This can be used to guarantee that the energy consumption information of P2P energy traders is only accessible to those who are authorized. Additionally, while allowing for the execution of transactions on the Blockchain, privacy-preserving smart contracts can be used to guarantee the protection of participants' identities in peer-to-peer energy trading. Furthermore, anonymous transactions allow for the execution of transactions on the Blockchain while protecting the identities of participants in peer-to-peer energy trading. Conversely, zero-knowledge proofs are a method that enables data verification without disclosing it. This can be used to maintain the ability to execute transactions on the Blockchain while protecting the energy consumption data of P2P energy trading participants. Lastly, a group of parties can collaboratively compute a function over their inputs without disclosing them to one another thanks to Multi-Party Computation (MPC). Sensitive data, including energy consumption data, can be protected using this method.

The smart grid research community frequently uses the sophisticated laboratory testing methods described by Montoya J. et al. [23] to test and validate the performance of smart grid systems under various conditions. These methods include real-time simulation and hardware-in-the-loop (HIL) techniques. First, real-time simulation is a technique that uses mathematical models to simulate the behavior of smart grid systems in real-time. With realistic simulations and real-world hardware, these methods enable researchers to test smart grid systems in a controlled environment. This makes it possible for researchers to evaluate how well smart grid systems function in different scenarios and spot possible problems before they arise. Hardware-in-the-loop is another topic that was discussed. It is based on testing the functionality of smart grid systems using simulations and real hardware, like actuators and sensors. This makes it possible for researchers to verify simulation results and test how well smart grid systems operate in real-world scenarios. Researchers can also exchange resources and work together on smart grid research projects through the Smart International Research Facility Network (SGIRFN), a network of research facilities that perform sophisticated laboratory testing of smart grid systems using real-time simulation and HIL techniques. The Power Hardware-in-the-loop (PHIL) is an extension of Hardware-in-the-Loop (HIL) that allows the integration of power systems and power electronic devices into the simulation environment. This makes power electronic-based systems and their interactions with the power grid more easily studied and investigated. Finally, cybersecurity testing is another advanced laboratory testing method used to verify the security of the smart grid systems and find vulnerabilities.

Aslam Z. et al.'s approach [24] for detecting and preventing electricity theft in smart grids combines deep learning and ensemble learning techniques. Thus, data from smart meters and other sensors can be analyzed using deep learning, a kind of machine learning that employs neural networks to analyze massive volumes of data, to find patterns and anomalies that might point to theft. It is possible to combine the predictions of various deep learning models to increase the accuracy of theft detection with the aid of ensemble learning, a technique that combines the predictions of multiple models to increase the accuracy and robustness of the overall system. Unsupervised learning can also be utilized to find patterns and anomalies in the data, which is helpful in identifying novel techniques for electricity theft that have never been observed before. It can be used to find anomalous consumption patterns that might point to electricity theft in addition to anomaly detection, a method for spotting odd patterns or behaviors in the data. Lastly, to increase the precision and resilience of electricity theft detection, the combined deep learning and ensemble learning methodology can be applied in conjunction with other strategies like data visualization, statistical analysis, and rule-based systems.

Blockchain technology can offer a transparent and safe platform for managing energy data and transactions on the energy internet, according to Zeng Z. et al. [25]. To fully grasp the potential of Blockchain technology in the energy internet, one must stay up to date on the most recent developments and trends in the field. By offering a safe and open platform for the administration of energy data and transactions, blockchain technology can be utilized to improve the information security of the energy internet. Energy data security and tamper-proofness are guaranteed by the immutable record of all transactions, which is one of the main advantages of using Blockchain technology in the energy internet. Additionally, it can offer a decentralized architecture, which strengthens its defenses against failures and attacks. Moreover, Blockchain enables the creation of smart contracts, which are self-executing agreements in which the terms of the sale and purchase are directly encoded into computer code. This can be used to guarantee that energy transactions are carried out fairly and transparently by automating their management. Identity management, a digital identity for entities and devices on the energy internet, is yet another feature that can be developed and may help to increase the energy internet's dependability and security. Similarly, an unchangeable record of the source of energy can be obtained through Blockchain technology. This technology can even be used to improve the cybersecurity of the energy internet by providing secure and transparent record-keeping, which enables quick and effective incident response. It can also be useful in ensuring the traceability of renewable energy and preventing greenwashing.

Salvatti G.A. et al. [26] discuss how to integrate EVs into smart grids as efficiently as possible using V2G and G2V techniques. To increase the grid's overall performance and efficiency, multifactor optimization, smart charging, and intelligent energy management systems can be employed. By doing this, you can lower the price of charging EVs and increase grid stability. Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) techniques can be used to optimize the integration of electric vehicles (EVs), which are a growing component of the energy system, into smart grids. EVs can charge or discharge energy to and from the grid using V2G, depending on the cost and availability of energy. By supplying extra energy during times of peak demand and absorbing extra energy during times of low demand, this can aid in maintaining grid balance. On the other hand, depending on the cost and availability of energy, G2V enables the grid to charge or discharge energy to and from EVs. By supplying more energy during times of peak demand and absorbing extra energy during times of low demand, this can also aid in maintaining grid balance. One of the primary topics covered in this course is multifactor optimization, which is the process of weighing several variables, including energy cost, carbon emissions, and vehicle range, when deciding how to charge and discharge electric vehicles. This may contribute to improving the grid's overall performance. Likewise, intelligent charging holds significant importance. It consists of a method that optimizes EV charging by utilizing real-time data on energy prices, grid conditions, and vehicle usage. This could lower the overall cost of charging EVs and increase grid stability. Finally, by forecasting the production of renewable energy, enabling dynamic pricing, and predicting energy consumption, Intelligent Energy Management Systems (IEMS) can be used to optimize the operation of V2G and G2V.

The authors Ali S. et al. [27] provide a photovoltaic-battery system-based optimization-based power usage scheduling strategy for demand-side management in smart grids. One method used in smart grids to control energy demand is called demand-side management, or DSM. The performance of DSM in smart grids can be enhanced by utilizing a photovoltaic-battery system (PV-BS) in conjunction with an optimization-based power usage scheduling approach. The Photovoltaic-Battery System (PV-BS), a system that generates electricity using solar panels and stores it in batteries, is the first topic to be discussed in this paper. This can be used to lessen the need for energy supplied by the grid and offer a dependable source of energy during times of high demand. One can determine the best method to optimize this operation in conjunction with optimization, which is the process of determining the best solution to a problem by considering multiple factors like energy cost, carbon emissions, and battery state of charge. Power usage scheduling, or the process of arranging the use of energy over time, is yet another theme to consider. Along with energy forecasting—the process of projecting future energy production and consumption—this can be used to make sure the PV-BS is used as profitably and efficiently as possible. By anticipating times of high demand and modifying energy usage accordingly, they can help optimize the PV-BS's performance. Finally, the process of gathering data on energy production and consumption in real-time is known as real-time monitoring. By modifying the energy consumption in reaction to changing circumstances, this can be utilized to maximize the performance of the PV-BS. The authors come to the conclusion that DSM performance in smart grids can be enhanced by employing an optimization-based power usage scheduling strategy with a PV-BS. It is possible to lower energy costs, increase energy efficiency, and lower carbon emissions by optimizing the PV-BS's operation, forecasting energy consumption, and tracking energy usage in real-time.

According to Singh U. et al. [28], wind power production in smart grid environments can be predicted using gradient boosting regression, which is based on machine learning. Gradient boosting is a technique that builds a strong model that can accurately predict the output by combining several weak models, like decision trees. When dealing with complex and non-linear relationships, which are frequent in forecasting wind power production, the technique is especially helpful. This method uses gradient boosting model training with historical wind power production data. Based on the current and predicted weather, the model can then be used to predict future wind power production. The smart grid can more accurately forecast wind power availability by employing gradient boosting regression based on machine learning for wind power production forecasting. This improves energy dispatch and reduces the need for fossil fuels. This could lower the grid's carbon footprint and increase its overall sustainability. All things considered, gradient boosting regression based on machine learning for wind power forecasting can be a step toward a smart grid that is more sustainable and intelligent.

Lithium-ion capacitors (LICs) are energy storage devices that combine the high energy density of lithium-ion batteries with the high power density of supercapacitors. They are mentioned in the paper Karimi D. et al. [29]. Their potential uses in smart grids are numerous and include load leveling, peak shaving, and frequency regulation. Thermal management, however, places a limit on the lifetime of LICs. In smart grid applications, an ideal thermal management system can help LICs last longer. Heat sinks, fans, and liquid cooling are examples of passive and active cooling techniques that can be used in this system. Furthermore, through efficient control and dissipation of generated heat, the thermal management system can be designed to maximize the temperature of the LICs. Moreover, the cooling system can be modified in accordance with the temperature of the LICs by using thermal management algorithms. These algorithms, which learn the behavior of the LICs and forecast their temperature, may be based on machine learning techniques. In smart grid applications, an ideal thermal management system can help LICs last longer, increasing their dependability and affordability. In the end, this may result in smart grid energy storage that is more reliable and effective.

A thorough review of the state of the art in Trust Management (TM) is presented by Y. Liu et al. [30]. It is based on a survey on BC-TM in IoT and uses two combined approaches: a set of evaluation criteria that a TMS in IoT should meet, followed by a taxonomy of TMSs, and it concludes with a thorough review of BC-TM in IoT using the proposed criteria. Maintaining trust relationships, spotting malicious nodes, and improving system security are all potential benefits of trust management (TM). Ultimately, a number of unresolved issues are highlighted and recommendations for future research directions are made in light of the review.

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	x											
4			x											
5	x	x												
6	x													
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28									x					
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30					x		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).

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