INTERNATIONAL JOURNAL OF INDUSTRIAL MANAGEMENT (IJIM)
ISSN: 2289-9286 e-ISSN: 0127-564X
VOL. 13, ISSUE 1, 408 – 421
DOI: https://doi.org/10.15282/ijim.13.1.2022.7365

ORIGINAL ARTICLE

IMPLICATIONS OF BLOCKCHAIN DEPLOYMENT IN ENERGY SUPPLY CHAIN MANAGEMENT: REPORT INTEGRITY

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ABSTRACT – The recent strategic deployment of blockchain technology has demonstrated its capacity to provide a ledger platform that can be utilized to secure and effectively manage large scale of data. However, there is little effort to conceptualise the blockchain to facilitate energy supply chain management for report integrity. This study has conceptulized how blockchain technology can solve the challenges of energy supply chain management and energy reports' integrity. Critical review of past literature indicates that blockchain technology offers transparency of energy production and consumption reports. Blockchain keeps all the transactional records and guarantees security, and decentralization between the blockchain network. We have reviewed 121 relevant papers. Through the literature review, this study found blockchain is a suitable option for the integrity of energy reporting in energy supply chain management. It can be concluded that blockchain can help to alleviate the issues of transparency and cost related to energy reporting. This study recommends taking the lead to track energy use and participate in energy reporting using dependable technologies to increase company integrity and efficiency.Decision and policy makers should offer incentives and include regulations on energy reporting requirements.

ARTICLE HISTORY
Received: 26-1-2022
Revised: 8-2-2022
Accepted: 17-3-2022

KEYWORDS
Blockchain
Energy Reporting
Energy Management
Energy Supply Chain
Integrity

INTRODUCTION

In the 21st century, fast business decision-making ideally revolves around technology. With the increasing need for modernisation, people can embrace modern technology. From remote control tools to voice notes for giving commands, new technology has improved our daily lives. Technologies such as virtual reality and the Internet of Things have gained traction in the last decade, and now a new addition to the community will concentrate on blockchain technology. Blockchain is the groundbreaking technology that miraculously affected numerous industries when the first modern Bitcoin implementation was launched in the markets. Bitcoin is a type of digital currency (cryptocurrency) that may be applied to exchange in the place of fiat money. Also, the technology that underlies cryptocurrencies' performance is called a blockchain. Bitcoin was the first fully developed blockchain and cryptocurrency network introduced by Satoshi Nakamoto in 2008. He used the term "a pseudonymous blogger" to give privacy by not using real names for security (Chen & Bellavitis, 2020). Blockchain uses a digital identity service to match individual identity (e.g. pseudonyms). This allows a secure and anonymous verification model (Zhang et al., 2017). Zyskind and Nathan (2015) proposed a decentralised blockchain platform covering three entities. The first entity is users who have interaction with the application. The second entity is a service that offers the application and processes users' data for business and operation. The third entity is a node that rewards for keeping the blockchain as an exchange. Therefore, users can control their data since mere pointers are stored about them.

The expansion of distributed energy resources, including a network of autonomous microgrids, is transforming the landscape of power distribution systems. The efficiency, dependability, resilience, security, and sustainability of electric power services are all managed through networked microgrids. Blockchain offers a reliable and robust platform for launching distributed data storage and administration (Li et al., 2019). Because of the growing demand for security and privacy due to IoE centralisation, new developing technologies such as blockchain, which may provide a completely decentralised and autonomous scenario employing encryption and smart contracts, are becoming more popular (Sadawi et al., 2021). The blockchain applications are agriculture, healthcare, manufacturing, and financial sectors. By incorporating blockchain into the IoE framework, a more secure, rapid, transparent, energy-efficient, and low-cost operational solution can be achieved.

Blockchain allows multiple electric utilities to interchange energy and conducts energy transactions without using a third party. All network members can observe and validate transactions, allowing for secure energy trading. A miner node verifies each record before adding it to the chain (Hald & Kinra, 2019). A record is validated by a miner node using a consensus technique before being added to the chain. Records linked to energy transactions are saved on every network node to build trust without using a third party, allowing any transaction to be confirmed transparently on the network.

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Each block in the blockchain contains the block's hash before it, ensuring that records are immutable. Furthermore, smart contracts allow for the processing of processes to be automated. As a result, blockchain possesses all of the characteristics suited to address security challenges.

Blockchain is a data structure that keeps all the transactional records and guarantees security, transparency, and decentralisation between the blockchain network (Fernando et al., 2021). The network is made up of a large number of nodes that maintain a shared status collection and perform transactions that alter States. It is an easy but innovative way to completely automate and securely transfer information from point A to B. The cycle begins with forming a block by one party to a transaction. Most network nodes must validate transactions before ordering and packaging into a time-stamped block. This mining method is based on the consensus system the blockchain network has embraced (Christidis et al., 2021). Until attaching the new block to the chain, each network node will check the block to include legitimate transactions and then use a cryptographic pointer to reference the previous block (Azzi et al., 2019). When a database is stored on a ledger, modifying or altering it is incredibly difficult. There are many advantages to using blockchain technology compared to other traditional technologies.

- **Fraud control** - Hacking threats to company business will be reduced to a greater extent.
- **No hidden fees** - There is no need to pay for centralised institutions or intermediary facilities, as blockchain provides a decentralised platform.
- **Security** - With blockchain, the business process is better covered by a high degree of safety due to its digital signature and encryption.
- **Transparency** - Transactions are straightforward and, therefore, convenient and easy to monitor.
- **Account reconciliation** - The reconciliation of accounts can be automatic
- **Access levels** - Enterprise blockchain technology helps companies to make use of varying accessibility rates
- **Speed** - With the support of blockchain, companies can do faster transactions because there is no need to have payment mechanisms that minimise costs and improve processing speed.

Individuals have a growing misunderstanding that Bitcoin and Blockchain are the same but different. Bitcoin is one of the applications developed by blockchain technology. Besides Bitcoin, blockchain technology can be used to develop various applications (Khattak et al., 2020). Literature on blockchain has incorporated some features such as the Internet of Things (Miglani et al., 2020), smart contracts (Hasankhani et al., 2021), cryptocurrency (Lee, 2019), and traceability technique (Sunny et al., 2020). Blockchain allows universal solutions to support renewable energy production that is quick and easy to implement. It offers a global open platform for renewable ownership and investment (Tsao & Thanh, 2021). Investors can fund renewable energy projects transparently and securely, allowing them to lend money for green energy growth (Miglani et al., 2020). A smart contract can also help incentivise energy projects by acting as a support mechanism (Hewa et al., 2021). However, there is limited evidence on how blockchain technicality can enable transparent energy consumption reporting and the energy supply chain management integrity. Blockchain technology's security and transparency advantages provide a powerful and trustworthy path for transparent energy reporting and energy supply chain management. Therefore, this article explores the previous literature on blockchain technology to draw inferences towards energy reporting integrity.

This study examines previous blockchain literature to conceptualise energy report integrity in energy supply chain management. The literature review section follows, with subsections on (1) blockchain structure, (2) blockchain types, (3) blockchain function, (4) blockchain security and privacy, (5) report integrity in energy supply chain management, and (6) challenges and research issues in designing blockchain for the energy supply chain. First, the method for reviewing the literature is discussed in the following section. Then follow by the results section, followed by a discussion and conclusion section.

LITERATURE REVIEW

The Structure of Blockchain

Blockchain is a series of blocks and includes a complete set of transactions logs, for example, a traditional public ledger (Chen, 2018). The block usually includes main data, the previous hash, present hash block, timestamp, and other important details.

i) **Main data**: Depending on the form of service provided by the blockchain, e.g. logs of transactions, records on bank clearance, or Interner of Things data records.
ii) **Hash**: It was hashed to a code when a transaction was executed, and transmitted to every node. Since it could include many transaction records (maybe more than a thousand) inside the block of a single node, it also applies the Merkle tree's function to produce a complete hash.
iii) **Timestamp**: Block times created.
iv) **Other Information**: Like a digital signature, Nonce value, or additional data defined by the user.

Types of Blockchain

The blockchain network might be make-up from a handful to millions of nodes globally. Based on the network layer structure, including node rights for accessing, verifying, and adding the ledger transactions and network structure, three types of networks blockchain generally referred to as public, private, and consortium (Perera et al., 2020) as shown in Figure 1. The discussions about the three blockchains are as below:-

Public Blockchain

A public blockchain is called the permission-less blockchain. This type of blockchain is a decentralised network available to all network members. Any node can connect and exit the network. The identification between the parties is either pseudonymous or even fully anonymous (i.e. before the transaction, the transacting parties do not know each other). Furthermore, everyone can search the blockchain's overall history and make any transactions through it. The participants can view all transactions. In the network i.e., everyone is granted the right to change the transaction. For example, everyone could ever be a novelist (Sankar et al., 2017). No central body controls membership or decides the readers or authors. Using cryptographic algorithms can help build the layout of such an illegal blockchain that ensures a secure network.

Private Blockchain

The private blockchain is referred to as the permitted blockchain. A version of the private blockchain managed distributed ledger where one entity controls the decision-making and validation process. This form of blockchain is a private network that maintains a public transaction record only available to those who have been prevalidated. Unlike the public blockchain, private blockchains are used by trusted participants. All the nodes in the private blockchain are authenticated, and other nodes are recognised for their identity (Dinh et al., 2017). The overall network power is in the owners' pockets. In addition, private blockchain rules and regulations can be amended according to various permission rates, access, membership numbers, authorisation, and so on. Private blockchains can operate alone or might also merge with other blockchains. Typically companies and organisations usually use these. Therefore, in private blockchains, the confidence required is higher among participants.

Consortium Blockchain

Offen named permitted blockchain and viewed as a hybrid platform among public blockchains platforms. Rather than allowing every consumer to participate in the transaction verification process or allowing only one entity to be provided with complete power, some chosen groups are decided in the blockchain consortium. This requires only a small consumer base to engage in consensus. For example, imagine a community or ten-bank network linked to the blockchain network. In this case, we might assume that seven out of ten had to concur for a block to be legitimate. Although this structure involves a certain degree of centralisation, users may write or read authorisations for others. This contributes to consortium blockchains being partly decentralised in architecture. Private blockchains preserve data privacy without consolidating control into a single entity.

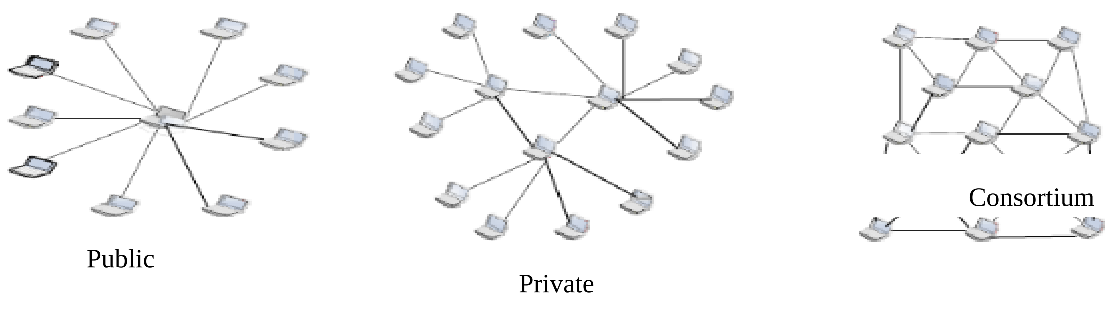

Figure 1. Types of Blockchain by Perera et al. (2020)

Blockchain Function

A blockchain contains either data or information in the block itself. The first digital cryptocurrency, called Bitcoin, used blockchain technology. A block within a network of blockchains stores some info together with its previous block hash. A hash represents a number and letter string generated by hash functions. The hash function is a math function used to convert several characters into a string of a specific number of characters. Just a minor alteration in a string produces a new hash entirely. Blocks are linked via unique hash keys, which makes blockchain secure. When there are transactions within the blockchain network, nodes validate such transactions. Such nodes are named miners in the Bitcoin blockchain and use the proof-of-work (PoW) principle to operate and verify network transactions.

Proof-of-work involves hosting and involvement of computer nodes in a blockchain by continually comparing the value of hash they generate with the value of hash given by the blockchain algorithm for the current block, calling mining

(Dolan et al., 2019). For the validity of a transaction, every single block has to link to its preceding block hash. The miner who generated proof-of-work was remunerated at block formation with the currency of blockchains which was developed purposes for reward only. This is one of the reasons for mining too. A reward for cryptocurrencies is checked after matching the hash that those cryptocurrency miners seek (Maček and Alagić, 2017). The up-to-date cryptocurrency is documented as being the miner's own. The most recent block in the blockchain network is completely registered, proof-of-work digitally signed -the hash value that is now labeled into the latest block. The violation will be identified because the updated hash may not fit the original. This means the blockchain is unchangeable because any modifications made to the blockchain are mirrored through the entire network and are easily detected.

Figure 2 illustrates how a transaction gets into a blockchain, and here are the steps on how blockchain allows for transactions operation in the network:

i. A network of blockchains uses private and public keys to build a digital signing that guarantees protection and consent.

ii. When the authentication is achieved via these keys, the authorisation requirement occurs.

iii. Blockchain enables network participants to perform mathematical verification and get an agreement to decide on some particular meaning.

iv. When making a switch, the sender uses their private key and declares the information on the transaction through the network. As a result, a new block will be generated, and inside the block include information like digital signature, receiver's public key, and timestamp.

v. The information of the block is transmitted over the blockchain network, and the validation process begins in the network.

vi. Miners in the network continue to solve the transaction-related mathematical puzzle to handle it. However, they need to spend their computing resources to solve this puzzle.

vii. The miner collects bonuses in bitcoins after first solving the puzzle. These problems are defined as mathematical proof-of-work (PoW) problems.

viii. After most network nodes arrive at consensus and agreement, the related block is ready to stamp and included in the existing blockchain. This block can include everything from messages to money through to data.

ix. Once the current chain server is integrated with the new block, the current blockchain copies for all nodes on the network are changed.

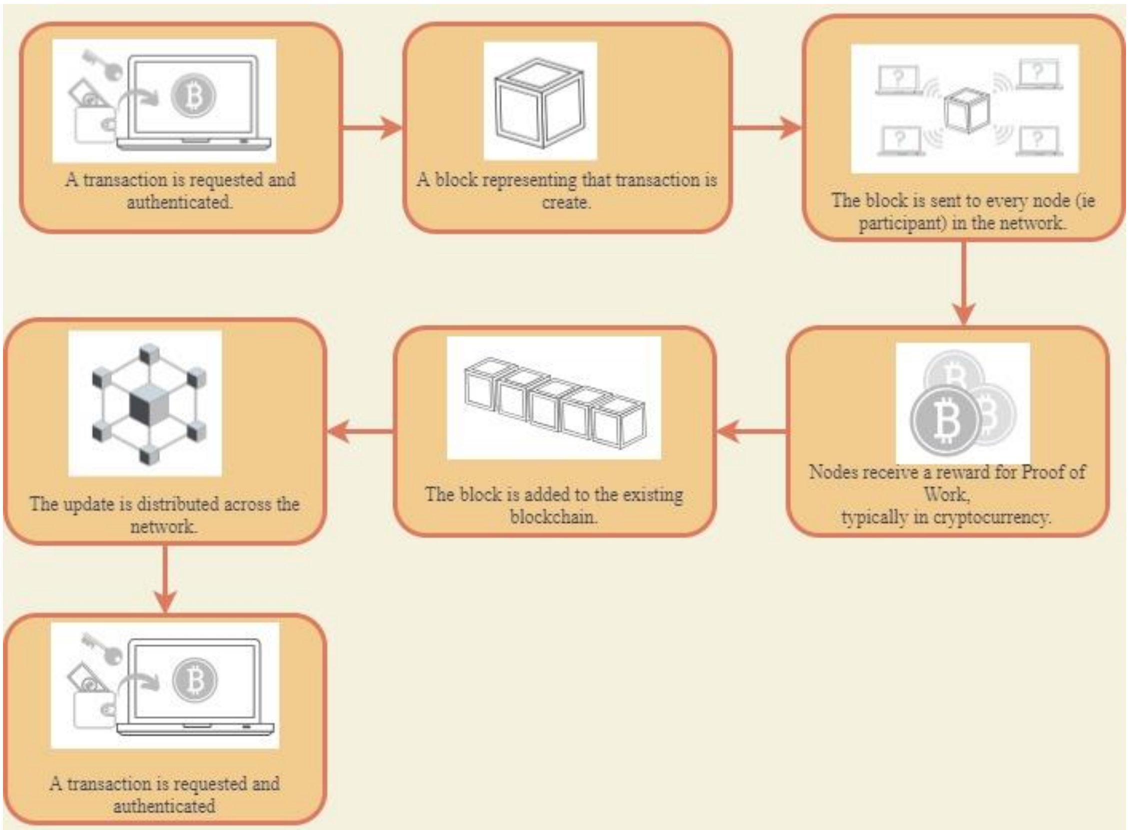

Figure 2. How the Transaction Gets into the Blockchain.

Security and Privacy

Modern decentralised IoE technology, blockchain provides additional security and optimisation. Cyber attacks are resistant to blockchain because there is no single point of failure. Blockchain data are resistant to alterations and attacks via a distributed ledger. The Merkle hash value prohibits any transaction from being modified illegally. A Merkle hash tree is a binary tree in which each internal node carries the result of applying a one-way hash function to the concatenation of the node's children. The leaves carry the hash of one tuple of the outsourced relation. The data owner signs the Merkle hash tree's root and distributes it to authorised users. The value of a specific attribute sorts the tuples in the tree's leaves. Without a centralised infrastructure, the framework improves authentication and confidentiality reliability. Blockchain is resistant to cyber-attacks because there is no single point of failure. Kim and Huh (2018) suggested the smart grid's cyber security danger and solution. The application of smart contracts in blockchain to improve a smart grid's speed and security (Mylrea & Gourisetti, 2017). Liu et al. (2018) used data coins and coins to apply blockchain to energy transactions to improve security on electric car cloud and edge computing services. Gai et al. (2019) argued that advanced linking attacks could be protected. By introducing noise in the network, this approach investigated privacy concerns in blockchain-based energy trading systems. An account mapping approach is utilised to prevent intruders from directly accessing the data when selling energy. Privacy and anonymity for secure energy trading include maintaining a central database to map energy bids and demand response (Kvaternik et al., 2017; Laszka et al., 2017).

Report Integrity in Energy Supply Chain Management

The *integrity* word means the state of being untouched. Integrity is also defined as being complete, whole, entire, and unbroken. It also means having the following moral qualities: sound, honesty, corruption-free, especially the fulfilment of contracts, and trustworthiness (Bauman, 2013). In this study, integrity in reporting energy consumption implies the soundness of reports, trustworthy, correct, and transparent reports. Therefore, the term integrity in energy consumption reporting in the supply chain indicates trustworthiness explicitly in energy reporting.

Blockchains have recently been utilised to construct green energy certifications. For example, solar panels allow prosumers to generate electricity and sell it to energy companies. A green certificate verifies that electricity was generated using renewable energy sources. Instead of sending the manual record to a centralised agency, the power station's smart meter record it immediately and upload it to the blockchain in real-time. Standardising renewable resource certificates improves energy market transparency and gives plant operators more alternatives (Jansen et al., 2016). Imbault et al. (2017) are the first to propose blockchain to generate green certificates.

Furthermore, the Guarantee of Origins (GaOs) directive was developed in 2009 to label energy derived from renewable sources. Guarantee of Origin is a standard that allows consumers and businesses to buy a preferred energy source based on their desired technology, geography, producer profile, or other critical criteria. It specifies energy sources. It defines energy sources, identities, sort, and geography of energy generation. GaO allows for consistent pricing when trading and purchasing energy. Castellanos et al. (2017) used Ethereum and smart contracts to simulate a blockchain and sell tokenised GaO to clients ready to profit from renewable energy suppliers. Tokens in GaOs are transferred directly between renewable energy providers and consumers via blockchain. Another possible use of blockchain is to provide security for ownership records, which are utilised to provide energy certificates to utilities. Individuals with credentials have their records on the blockchain that cannot be altered.

Energy industry decision-makers and utility firms have stated that blockchains solve some of the industry's problems. According to the German Energy Agency, blockchain technologies impact the efficiency of existing energy practices and procedures, encourage the growth of IoT technology and online systems, and provide advancement in peer-to-peer energy trading and geographically dispersed production (Mengelkamp et al., 2018). Furthermore, blockchain technologies can significantly enhance present energy and utility practices by streamlining internal operations, enhancing customer service, and lowering prices (Andoni et al., 2019). The advent of dispersed energy resources and information and communication technology is causing energy systems (ICT) transition. The energy system's increasing decentralisation and digitalisation are key issues requiring examining, developing, and applying novel paradigms and distributed technologies. Blockchains may offer a potential alternative for controlling and managing increasingly distributed complex energy systems and microgrids due to their inherent nature (Kumar et al., 2020). However, it is difficult to integrate small-scale renewables, distributed generation, flexible services, and consumer participation in the energy market.

Using distributed ledger technologies in wholesale autonomous trading operations is one possible use. Brokers, trading agents, exchanges, price reporters, logistic suppliers, banks, and regulators are necessary third-party intermediaries in wholesale energy markets. The important entities and actions involved in financial trade between two corporations are summarised in Figure 3. Current techniques involve manual post-processing and additional communications to integrate information kept independently by each part of the transaction. As a result, present methods are slow and time-consuming, as transactions must be checked and reconciled many times from the beginning to the end (Andoni et al., 2019). Due to the slow speed of transactions and exchanges, frictional costs are excessive for small-scale and distributed generators, which are effectively shut out of the market.

It is recommended to use blockchain technology to track energy consumption and ensure the supply chain's integrity (Fernando et al., 2021). For example, a generating unit can trade directly with a consumer or an energy retail provider via autonomous trading agents, bypassing the middleman, using distributed ledger technology and smart contracts. The agent would look for the most acceptable bargain in the market that meets a customer's anticipated need for a specific period. The agreement would be securely recorded in the blockchain and executed at the agreed-upon delivery time. Payments would be made automatically at delivery time, as per the contract. All participants and the system operator would access transaction data through a single access point. Similar use cases would necessitate significant regulatory modifications, with substantial implications for the function of the regulator.

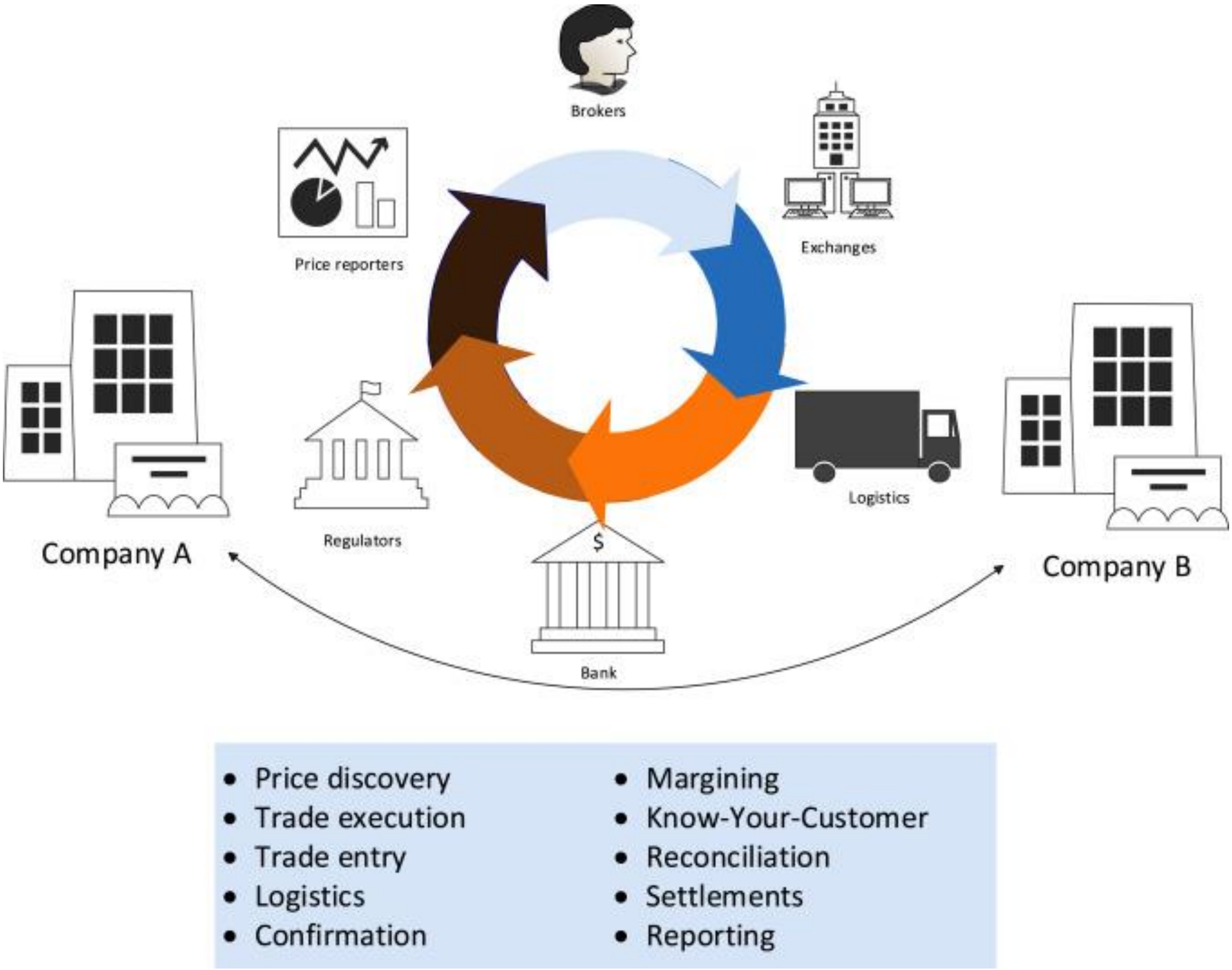

Figure 3. Third parties and process normal energy commodity transactions by Andoni et al. (2019)

Challenges and Research Issues in Designing Blockchain for Energy Supply Chain

Blockchain rules and regulations must be standardised. For example, according to Mengelkamp et al. (2018), a malicious transaction requires 51 percent of the majority votes to terminate or modify data in the network because of the immutable attribute. Furthermore, due to constraints such as the 51 percent approach, smart contract security, and key management hazards, blockchain technology is still not mature enough to be widely acknowledged by researchers. One of the most important issues to discuss blockchain is its high energy usage (Fernando & Saravannan, 2021). However, the usage of a private or consortium blockchain can aid in the reduction of energy consumption. Another critical issue is the added expense occurring because each producer-consumer transaction is transmitted and stored across the entire network.

Furthermore, blockchain suffers from scalability concerns and a lack of acceptability. For example, there are hazards linked with blockchain due to a lack of long-term use and experience. Notably, if distinct public keys are linked, achieving anonymity with dynamic public keys can fail.

Therefore, the concept of numerous public keys in Bitcoin does not safeguard the anonymity of the identity (Hong et al., 2018). The same difficulties apply to the energy market built on blockchain. Blockchain's distributed, and decentralised approach may conflict with centralised grid management. This innovative technology may impact energy company management, production safety, and macro energy sector regulation (Sun et al., 2018). Furthermore, the blockchain consensus process uses a significant amount of computer resources and electricity in practice, resulting in low system throughput and considerable system latency. In addition, the blockchain necessitates higher operational and compatibility capabilities for existing platforms. Finally, the blockchain must address the issue of designing an interaction mechanism to aggregate and exploit the group intelligence of distributed consensus nodes.

METHODS

This study searched databases for studies from 2015 to December 2021 using the phrases "blockchain and energy supply chain management," "energy reporting," and "blockchain and energy performance." Web of Science, ScienceDirect, and Emerald were the most important databases. The articles' keywords, abstracts, and titles were used to conduct the searches. The three types of findings were technical papers, scientific publications, and reports on special issues published by a specific body. In the literature, articles on blockchain or energy management systems were identified. Studies on energy supply chain management, energy reporting integrity, blockchain, and energy management, on the other hand, were not found in substantial numbers. Therefore, the focus of this study was on publications published after 2015 to find out the latest trends on blockchain technology. The goal was to find blockchain deployment in energy supply chain management and the potential blockchain use on the integrity of energy reporting.

The publication search for energy supply chain management and integrity energy reporting is divided into two areas that employ particular keyword clusters. The first set of terms involves energy management, the energy supply chain, and energy efficiency. Energy reports, transparent reporting, and energy audit reports are the second keyword cluster for integrity energy reporting. Furthermore, the search was conducted with two groups of keywords: blockchain and energy supply chain management. The first is blockchain technology, which manages the energy supply chain. The integrity of energy reporting is the other. General keywords (such as blockchain*, energy*, or efficiency*) are utilised for each search phrase. The "AND" command was used to find articles or papers containing all three desired terms.

There were two parts to the publishing review. The first step was to collect all relevant articles using the research terms as a guide. The titles and abstracts of the papers were evaluated to choose the most relevant ones to the research. The second step consisted of a more thorough evaluation of all of the papers that had been chosen. Only studies that evaluated, enhanced, or applied the categories above were collected from each database, and double-counted publications were removed. Out of 521 publications found in the original search, 121 were relevant. Again, the authors studied the titles, abstracts, and content of the papers and chose those that were relevant to the research.

RESULTS

Based on the 121 publications retrieved, it was found that blockchain technologies are not just a single application method. It includes cryptography, mathematics, algorithms together with economic models, integrating peer-to-peer networks, and using algorithms distributed by consensus to overcome conventional distributed database synchronisation problems. The blockchain technologies contain six main components, as discussed below:-

Decentralisation - The trusted core agency must check the transaction for traditional centralised transaction structures, resulting in the main servers' cost and efficiency discrepancies. In comparison with the centralised model, blockchain does not need a third party (Perera et al., 2020). Consensus algorithms are used in blockchain in the distributed network to preserve data integrity.

Security – Blockchain network uses public-key asymmetrical cryptography encryption techniques to protect the integrity of the encrypted information and avoid scams. The encryption function ensures private data security, while digital signatures ensure authenticity, quality, and irreproachability (Sun et al., 2018).

Immutability – The data saved in a blockchain is known as unchangeable because it is protected by peer-to-peer networks of participants (Tsao & Thanh, 2021). After the documents have been transferred to the blockchain, transactions can not be reversed, resulting in the ledger being a permanent record of all past transactions. Blockchain only enables the creation and reading (CR) operations.

Auditability - Bitcoin blockchain stores user data based on the Template Unspent Transaction Output (UTXO): every single transaction may apply for all previous unspent transactions. Once the transactions are recorded in the ledger, their status change from unused to spent; therefore, transactions can be checked and monitored easily (Chen, 2018).

Transparency - All transactions are open and reported to the public in a shared blockchain (Yli-Huumo et al., 2016). The transaction reports should be made available so that they are accessible to each participant in the market, or the level of transparency should be regulated.

Anonymity – Transaction in Blockchain usually uses private and public keys, so the individual may keep anonymous to preserve their privacy and enable third parties to establish their identity (Sunny et al., 2020). It allows for the right to retain and protect transaction privacy.

Despite blockchain's great potential, it faces numerous challenges, restricting the large use of blockchain technology. The section discusses some of the challenges of blockchain technology and its limitations (Alam Khan et al., 2020).

Scalability - With the transactions number are growing daily, the number of blockchains is becoming voluminous. Therefore, every node must store all transactions on the blockchain to validate them, and they must check whether or not the present transaction source is not being spent. Furthermore, Bitcoin blockchain can only operate approximately seven transactions per second based on the block size constraint and the timeline needed to construct a new block, which can not satisfy the processing required for a massive amount of real-time transactions. In the meantime, the block capacitance is extremely low; many smaller transactions may be postponed because miners favour certain large transactions with high costs (Lu et al., 2017).

Security - Regardless of their decentralised nature, blockchain networks can be vulnerable to various security threats (Alam Khan et al., 2020). Coordinated attacks by a majority (or sometimes even a large minority) of the miners on the ledger can reorder, delete and alter transactions. In addition, blockchain systems are vulnerable to conventional attacks on the network, such as service denial or partitioning. These attacks aim to reduce the number of miners involved or disrupt the miners 'network to avoid compromise, lower the threshold for attacks, or establish an inconsistent environment.

Waste Resources - The problem of energy conservation is not currently dealt with in computer engineering. Mining Bitcoins requires a lot of energy to safely and efficiently compute and validate transactions (Reynolds et al., 2017)**.** Different researchers against resource loss suggest several realistic approaches using PoW and PoS.

Data Privacy - Public blockchains lack data protection (Lu et al., 2017). Since there are no limitations to the user, any blockchain node can just enter the network to get the information inside the blockchain. They can just access and participate in the public blockchain that does not need permission. Therefore, the protection of data is a big problem for public blockchains. Those participants who concern themselves with information protection would just choose private blockchains. Private blockchain information protection, membership administration, networks, and other methods to approach data privacy problems in public blockchains have been introduced and implemented. On the other hand, the private information might be kept off-chain in public blockchain to ensure others noted do not have any access to that information (Lo et al., 2017).

Data Storage - The blockchain network is not ready to serve the big data because of the low speed of the data processor and the huge quantities of data in the network, according to Lo et al. (2017). Public blockchains have restrictions on how much data a blockchain can store (Lu et al., 2017). Most nodes must be authenticated and acknowledged for any transaction to be registered. The mining block creation process will also be delayed when a large volume of data is processed. Only the data most important to the blockchain will be on-chain to solve this problem, and all other data will stay off the chain.

Fork Problems - This problem is about decentralised agreement on node versions once the software is approved for an update. This is a critical problem because it involves a wide variety of blockchains. Once the latest edition blockchain software has been released, all network nodes have been modified to a new consensus agreement. The blockchain network nodes can break down into two categories: old and new nodes. Below are a few different conditions:-

1. The new nodes comply with the transaction of a blockchain network that is submitted by the old nodes
2. The new nodes do not comply with the blockchain network transaction that the old nodes send out.
3. The old nodes comply with the blockchain network transaction that is submitted by the new nodes.
4. The old nodes do not comply with the blockchain network transaction that the new nodes send out.

Due to the different conditions mentioned above, the problem of the forks can be broken down into two groups: soft and hard forks (Alam Khan et al., 2020).

Hard Fork means when a new edition of network or agreement arrives, which was not consistent with the earlier edition, the old nodes cannot consent to new node mining, and a single chain is split into two chains. Although new nodes were more efficient than old ones, older nodes will still maintain the suitable chain. When a hard fork happens, the existing network nodes must upgrade the network server. Those network nodes, which do not update, would not continue to function as normal. If more old nodes have not been updated, they will keep working on a separate blockchain network and the normal chain.

Soft Fork means new nodes didn't meet the existing mining node criteria when the framework comes with a new edition or arrangement, which was not in line with the previous edition. As the computational capacity of new nodes is greater compared to old nodes. Each block mining by the old nodes will not accept the new nodes. Yet, on the same chain, both nodes still will operate as usual. When a soft fork occurs, the existing network nodes do not need to update the new edition immediately. They allow for updating slowly. Not as Hard Fork, as nodes update, Soft Fork will only have a single chain and does not impact the performance and stability of the network. Nevertheless, Soft Fork renders old nodes do not know that it has changed the consensus norm, conversely on the idea that each node should check to some degree correctly.

The factor that makes companies reluctant to make an energy consumption report is that they are not transparent in running their business. The second factor is that the companies consider the energy consumption report unnecessary. Besides that, no regulation requires a company to release an energy consumption report specifically or voluntarily in best cases (Kim, 2019). Therefore, there should be efforts from governments to encourage transparent sustainability reports in general and energy consumption reporting in specific.

Based on findings, it was found that annual reporting only exists as declarative reports within non-financial reports. Energy reports are given less importance as many obstacles present, such as the complexity and number of data points across several intensive-industry processes. Besides that, no proper guidelines are available for proper selection and interpretation of energy consumption data for reporting. In addition, it is due to absences of top management commitment and low energy knowledge and awareness among the workforce toward energy efficiency (Fernando et al., 2018). Therefore, the level of experience of the energy team will not qualify to convert existing energy consumption data into relevant reported data. Another issue is that manual reporting makes it harder for the energy team and lacks technology such as advanced meters linked to blockchain technology or energy management software (Fernando, Tseng, et al., 2022). Consequently, manual reporting is time-consuming, fewer reports are generated, and lower monitoring from higher management levels (Tasrip et al., 2016).

DISCUSSION

Blockchain technology offers numerous benefits in managing the energy supply chain in a circular economy and ensuring sustainability. Security, visibility, transparency, immutability, decentralisation, and efficiency are compatible with the blockchain procedures. It is required to shift from the existing linear economy model to the circular economy model (Fernando et al., 2022b). Blockchain technology is used in various systems related to the functions and business processes of the energy industry. When the findings of literature review are investigated, energy management with blockchains, smart contracts, smart measurements, machine learning, and artificial intelligence techniques is easily recognised. Decentralised energy networks and microgrids may benefit from blockchain technology. Enabled by energy exchanges or distributed networks, local energy markets might drastically boost energy self-production and self-consumption, also known as meter operations, potentially affecting profitability and policy (Miglani et al., 2020).

Blockchain technology can improve energy management efficiency. Mining algorithms are used to aggregate energy use and conservation information. In a blockchain-based distributed ledger, it is possible to discover the appropriate position for waste heat recovery (Bürer et al., 2019). In addition, the Internet of Things (IoT) is used in blockchain to track real-time energy consumption. System administrators can use blockchain to acquire access to complete and reliable energy usage statistics. In addition, blockchain can be used to distinguish between renewable and nonrenewable energy sources. The unsustainable energy consumption may be measured and shown using blockchain and the Bitcoin algorithm. Although Bitcoin can function effectively as a blockchain technology platform and track energy usage, its scalability and long-term viability have been questioned (de Vries, 2018). Blockchain cryptography techniques help to ensure the integrity of reports. Information verification and identity protection can be encrypted using cryptographic technologies to provide confidentiality (Yildizbasi, 2021).

The blockchain database can help with energy supply chain management and the integrity of energy reporting. Standardised databases and methods can significantly improve auditing and regulation (Khaqqi et al., 2018). Smart contracts can manage and simplify energy supply management (Ahl et al., 2019). Blockchain technology allows many clients to connect and exchange services like solar energy stations and storage centres (Hassija et al., 2020). In principle, blockchains might be used for smart device networking, data transfer, and storage. Blockchain technology will assist smart grid systems and allow safe data sharing (Musleh et al., 2019). Blockchain technology can make operations like waste tracking and recyclable items in energy production and consumption more traceable (Kouhizadeh & Sarkis, 2018; Sarc et al., 2019).

CONCLUSION

Blockchain technology is a modern method with potential use for organisations, allowing encrypted transactions without requiring a central authority. A growing range of technology-based blockchain solutions emerged in 2009 with Bitcoin using blockchain technology. Blockchain technology has become one of the most important digitalisation tools in energy supply chain management. Blockchain technology can serve as a control mechanism with the rise of distributed energy systems and the demand for green energy. The blockchain's structure makes it compatible with smart grids and microgrids, also part of the energy sector's future. Every activity and energy transaction can be recorded, and no data can be changed because blockchain ensures the integrity of energy reporting, production, use, transmission, and storage. Even the usage of blockchain technology is still new, but it is widely understood and developed based on principles of cryptography.

Blockchain technology is still in the developing stage. It also has difficulties and limitations that hinder the blockchains' growth such as scalability, security, fork problem, waste resources, etc. However, there have some current approaches to solving these problems. For example, using proof-of-stake techniques will reduce the expense of computing resources such as hardware and energy costs. But the forking problem in blockchain cannot be removed because opportunities for change never end. Lastly, additional macroeconomic research should be undertaken to fully comprehend the effects of blockchain on the energy market, notably on consumers, benefits delivered, and the risk to clients. An equally crucial political science subject for scholars and policymakers to examine is how energy subsidies and renewable energy tax incentives interact with blockchain advancements. Furthermore, what institutions can govern the integrated systems that may grow, will the public accept new technologies such as blockchain or digital finance innovations in general, and the effects of these developments on society, including the environment.

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CONFLICT OF INTEREST

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ACKNOWLEDGEMENT

The authors would like to thank the Division of Research and Innovation at Universiti Malaysia Pahang for funding this study (RDU212701; UIC211502; PDU203220; PGRS190365).

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