Blockchain utility in renewable energy

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8.1 Overview of renewable energy and internet of energy

Fossil fuels are a nonrenewable natural resource that has fueled our economy by providing electricity for industries and homes. Our dependency on electric energy grows as our civilization gets more digitally savvy and sophisticated. On the other hand, renewable energy uses dynamically regenerating but fluid sources, like water, to produce hydropower, for example (Afzal et al., 2020). These resources have an essentially endless storehouse and can be produced for an infinite duration though they still have a constrained power supply per given period. India's renewable energy business is the world's fourth most appealing renewable energy market. As of 2020, India has been rated fifth in wind energy, fifth in solar energy, and fourth in renewable energy generation capacity. Fossil fuels, often known as nonrenewable energy, are restricted in supply, and at present consumption rates, they are expected to run out during the early 22nd century. This shortfall, as well as the known environmental difficulties associated with carbon emissions which is an inevitable fallout of burning coal to produce thermal power, has prompted a greater focus on alternative sources of energy, particularly renewable energies such as wind and solar power. Thus, society has turned to IoE for transforming the energy sector in several ways during the last decade. Firstly, the IoE intends to create a conscience intelligent energy infrastructure for information processing and use, resulting in reduced energy waste. Secondly, IoE has revolutionized the production, distribution, and transmission system by combining sensors, the Web, smart grid, renewable sources of energy, AMI, and autonomous techniques that has raised the efficiency of the system and cut costs while improving the performance of the electricity generation and distribution infrastructure. Thirdly, electricity producers have brought electricity market paradigm shifts by helping distribution operators grappling with the rise of distributed generation units concomitant with problems such as power volatility, demand-supply mismatch, and so forth, to adapt to the idea of local energy markets to efficiently reward and dispatch shared resources; while the steady transition toward dispersed renewable resources meant that power generation is becoming more weather-dependent and that this random nature of power generation necessitates new demand-supply management approaches among providers. Thus, on a warm day, there would

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be too much electricity produced, but there may be a shortage of energy on a cloudy day (Alladi et al., 2019). In such instances, the most important necessity is to maintain a balance between electricity generation and consumption. The regional electricity market is a small-scale subset of the electricity market, including renewable power trading among the channel's various utilities. However, the implementation of the local energy market necessitates a modern communication structure as well as a unique payment system. An intelligent planning and monitoring system is necessary to establish a coordinated, efficient, and sophisticated energy market that includes distributed energy resources, flexibility, and consumer visibility while using renewable sources of energy. This new technology will deliver a power system that is efficient, accessible, flexible, and autonomous. A smart grid system preserves stability by balancing electricity output and utilization among utilities. Microgrid ecosystems are commonly used to combine the energy infrastructure with distributed generation units.

Furthermore, electric vehicles, which are a key component of smart grid cyber-physical systems, have grown well in recent times as a result of their ability to provide a green, environmentally safe atmosphere. When electric vehicles are combined with wind and solar power plants, they provide superior storage and power stabilization services, which can help alleviate the fossil fuel problem (Apergis & Payne, 2012). However, the absence of charging facilities in the electricity sector limits the use of electric vehicles. The main characteristics of IoE are shown in Fig. 8.1.

8.1.1 Issues in internet of energy

Internet of energy technology could provide sophisticated communication among diverse electric utilities to create a single system. As the IoE market grows, so will

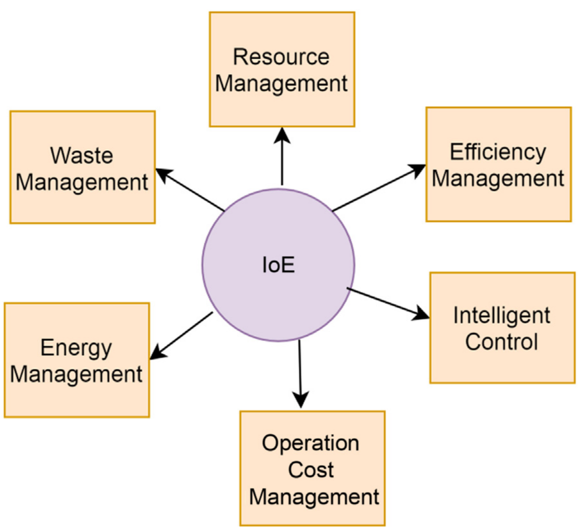

Figure 8.1 Characteristics of internet of energy.

the number of connections, communication instances, infrastructure complexity, and malware programs. As a result, there are numerous challenges in integrating various energy generation and use methods. Also, the primary purpose of this chapter is to take a look at the places where the combination of blockchain and IoE are strongest, where challenges are overcome in developing IoE from making a transition from centralized architectures to decentralized power markets.

8.1.1.1 Payment mechanism

A power grid spanning across nodes such as electric vehicles, microgrids, smart grids, and smart houses in an IoE smoothens the process of payment of power usage bills, which is then utilized for services such as load forecasting, flexible pricing prediction, and optimized energy usage planning. The price for electricity trading services in the power grid or decentralized energy supplies should be agreed upon between electricity companies engaged in the purchase process (Chen, 2018). Traditional payment options, such as debit cards, credit cards, and PayPal, require a trusted third-party bank or financier to exchange the user's banking details with merchants. Furthermore, exchanging bank details among nodes may raise privacy concerns and divulge electricity usage patterns, let alone pose a danger to confidential personal information, like name, email id, and location. Several solutions based on anecdotal payment mechanisms have been proposed to address the issue of online privacy loss. Although these solutions protect privacy, they are dependent on centralized structures and frequently need payment by a third-party auditor. The use of a pseudonym for every new transaction, on the other hand, can make it difficult to identify malevolent attackers.

8.1.1.2 Energy trading mechanism

In the IoT, peer-to-peer energy trading is critical but still poses some security and privacy concerns. Microgrids interconnect smart houses and streets, whereas current power infrastructure employs a big centralized grid that generates energy and transmits it over distances via transmission lines. Electric utilities, suppliers, and market agencies work together in transmission and distribution networks (Chitchyan & Murkin, 2018). Trading between smart buildings, residences with wind and solar power stations, electric cars and electrical grids to manage load peaks, hybrid vehicles and electric vehicles, renewable sources to grids, V2G and G2V are examples of P2P electricity market possibilities for IoE. Automated verification by third-party auditors such as brokers, traders, trading agencies, and banks is common in the current power trading sector, leading to high computational complexity and lower efficiency. As a result, several nodes with excess energy refuse to participate in the energy sale process for privacy reasons. Obviously, as the population grows, the IoE scenario will become more complicated. When a centralized organization fails under the weight of a tremendous workload, it might result in high operational costs. Furthermore, traditional energy supply companies provide utilities at set prices, making them less expensive.

8.1.1.3 Demand management

Since a huge quantity of energy is needed to recharge each electric car and renewable energies are unreliable, the transition to electric vehicles and renewable energy sources creates issues of resource scheduling and load variations for grids. Whenever the network nodes grow, so does the amount of transactional data, making substantial demand management more complex. Load management control is critical for the successful implementation of IoE technologies. Its goal is to produce an optimal load by balancing power usage activities (Ghosh et al., 2018). Some of the benefits of load management control include increased asset utilization efficiency, improved penetration and consistency for green energy supplies, bill savings, capacity expansion, volatility of stock reduction, administrative cost reduction, and controlling peak-hour loads. Energy consumption management, supply-side management, and changing economic response are used to describe predictive control management. The absence of an energy storage system is yet another reason to create a load management control system. In this setting, direct load management and price optimization are two extensively used demand response mechanisms.

8.1.1.4 Security threats

Cyber-attacks are one of the specific dangers to the IoE, as they jeopardize data's validity, availability, security, and integrity. Users and vendors are frequently concerned with the usefulness and affordability of IoE while ignoring cyber security. Because of the lack of privacy standards and procedures, the ever-increasing information flow obtained at edge devices is obviously at risk. As IoE technology advances, the number of nodes, buildings, and devices it connects to grows, increasing the attack vector for different cyber-attacks. Current security solutions that use public key encryption require verifiable other source authentication, posing a privacy risk. Furthermore, the usage of numerous communication techniques and communication systems exposes the power system to hackers by giving them access to personal details of electricity users like user identification and personal data. Malware, disseminated denial-of-service (DDoS), jamming attacks, hacking, and bogus data injection are all examples of cyber-attacks against the power system. Poor measurements and misleading data injection assaults during state estimation are other potential cyber-attack. Condition estimation is a technique for tracking and determining the current state of an energy system to ensure its long-term viability and efficiency. Dependency analysis is performed by the control center using the information from state predictions.

8.1.1.5 Pricing mechanism

Introducing dynamic pricing, in which power rates fluctuate dynamically over a period, is one technique to manage the real-time responses of users to market demand-supply conditions. The goal of dynamic pricing is to change the current cost of electricity based on market demand. This dynamically evolving pricing structure encourages the entire network to alter market forces as supply adjusts to demand in maintaining a market equilibrium in which the price is the tool in the hands of a conscientious electricity consumer. Thus, prices are low when there is little consumption and increased production, but they are high when there is high demand and limited production. It adjusts energy usage during peak hours, and customers may be rewarded for reducing peak-hour electricity usage. Customers are forced to adjust their usage of power to off-peak time as a result of high prices during peak hours. Smart meters can aid in this regard by evaluating the user's power consumption trends and sending him alerts of price hikes when usage has to be cut down and price cuts when usage can be accommodated. Genuine pricing, peak power rebates, and peak power pricing are examples of dynamic pricing schemes.

8.1.2 Blockchain preliminaries

The blockchain is a decentralized process that helps people to execute transactions without a central authority (e.g., instead of a bank looking after your paper securities, there are digital assets that have no actual assets backing them up but only a consensus in the network). It's a decentralized cryptocurrency that's duplicated across a network of peers, with each peer keeping a local record of transactions. Everybody can read that ledger given the public key (which is a hash pointer, a variable containing the address of the previous block, that also keeps a hash of the data stored in that address which makes the data in the chain read-only), but to write, the owner of a block needs the private key of the next block (that requires solving a hash function connecting the private key to the public key, but only the miner who finds a solution first according to what the consensus mechanism dictates will have found the private key) such that changing the record of valid transactions, even minutely, needs a mathematically astute mind to keep the change secret from others making the hacker's work not only impossible to do without informing all in the chain but also computationally difficult. People may use the same blockchain for a variety of purposes. For example, in the finance industry, a blockchain can be used as insurance in the shipping business. It can also be used to replace currencies or prepaid cards in digital money payments or to follow the distribution network (Goranovic et al., 2017). The strongest inventions in history have all been motivated by a desire to fill a void, and in the case of cryptocurrency, that void is one of trust. In economic interactions, the overall importance is linked to the necessity for two parties to trust one another. A third-party authority is necessary in the absence of a blockchain. In fact, by using a decentralized system, two parties can agree without the need for any intermediary, making commercial operations easier. Another difficulty we wish to avoid is centralization. Although the blockchain is naturally decentralized, there are instances where centralization emerges, resulting in a more vulnerable network. When centralization is achieved, an attacker will be able to exert control over the channel's status, selecting which payments are validated and which are dismissed. The basic properties of blockchain are shown in Fig. 8.2.

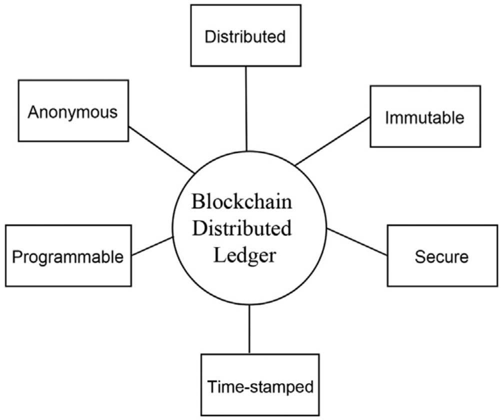

Figure 8.2 Properties of blockchain.

8.1.2.1 Block

A block made up of "data" and "header" is the most elementary component of the blockchain. It contains a portion of blocks which are consistent. The goal of hashing blocks is to store cryptographic keys—public key(a variable, called a hash pointer, pointing to the previous node and with a hash of the data stored in that node) and private key(this is the output of a hash function connecting the public key with the private key and with a consensus mechanism telling the miners what to look for)—in each new block's header that makes it difficult for a hacker to guess the private key of the block from the public key which only the miners, or nodes in the network, can solve by agreeing on all the information they can take as given about the blockchain and match to get a complete dataset to link with the previous block. Thus, we build a cryptographic chain. The enormous use of the cryptographic algorithm behind the consensus mechanism is what makes up the chain. Blocks are scrambled, and then each hashed string of digits is incorporated in the next block provided there is consensus, thereby maintaining the security of the network. The first block, known as a block header, has no preceding block, but all succeeding blocks have a progenitor.

8.1.2.2 Smart contract

Smart contracts, which are a part of business logic and can be included in the database, are computer programs that can be deployed by the blockchain and executed by the nodes when certain criteria or pre-defined terms are satisfied and are maintained on a blockchain. Smart contracts are often used to streamline the implementation of a contract so that all parties of the smart contract are sure of the output right away, without the need for any intermediaries or wastage of time. They can also automate a workflow, starting with the terms coded with "if/when...then..." conditions to make smart contracts run automatically when the conditions are met by the blockchain's nodes. When preset circumstances are satisfied and validated, the activities are carried out by a computer network. These activities could include transferring payments to the proper parties, licensing a vehicle, providing alerts, or delivering a ticket. When the contract has been concluded, the blockchain is modified. The advantages of a smart contract are

1. Speed, efficiency, and accuracy
2. Trust and transparency
3. Security
4. Savings.

8.1.2.3 Consensus mechanism

Blockchain solutions do not require a third-party organization that, contrary to the blockchain's network owners, holds power to sanctify a transaction depending on assets. Rather, blockchain uses cryptocurrencies that are not backed by physical assets but by digital assets and follows a decentralized consensus method to ensure the data and transactions are reliable and consistent. There are four basic consensus processes in extant blockchain systems. Firstly, the Proof-of-Work (PoW) technique is used by the two most common blockchain systems, Bitcoin and Ethereum (Imbault et al., 2017). The PoW technique is also used by Ethereum, and several other cryptocurrencies, including Peer Coin, Shadow Cash, and others, employ the PoS methodology. The PoW procedure is also referred to as mining, and miners are the nodes that tackle difficult mathematical riddles that necessitate a lot of computing power. Miners use a variety of mining technologies for resolving the transaction based on consensus, including CPU mining, Gpus mining, FPGA extraction, resource extraction pools, ASIC mining, etc. Secondly, the PoS, on the other hand, doesn't resort to resolving mathematical puzzles but determines who receives an opportunity to produce the next block through a randomized procedure. For the purpose of becoming a validator, blockchain individuals can start locking up their tokens for a set period of time. Users who have earned the status of validator will be able to create blocks. Validators could also be chosen based on the bitcoin's structure. Thirdly, individuals can stake their coins and choose a specific number of delegates in the Delegated Proof of Stake procedure. The importance of a participant's vote is determined by their stake based on, for example, his size of holdings. Lastly, responses to complex mathematical riddles are recorded in digital storage like hard disks using the Proof of Capacity approach. Proof of Time Elapses is the time process that chooses the creator of a new block randomly and fairly depending on the amount of time they have waited. A user's private key is compared to an authorized identity in Proof of Identity. Proof of Identification is a mathematical piece of evidence for a user's encryption key that is cryptographically connected to a specific transaction.

8.1.3 Blockchain in internet of energy

The three kinds of blockchain technology are permissioned, permissionless, and consortium. IoE is a possible use case for permissioned blockchain. The devices in the IoT continuously collect environmental data in terms of balancing peak demands and keeping the lights on. As a result, only minimal permissions must be allowed to certain sensor devices. As a result, several ideas for monitoring the effectiveness of blockchain in IoE have chosen authenticated and consortium type blockchains. Therefore, to develop a structure in the energy market that is free of disputes, legal laws and guidelines must be properly specified. All IoE nodes operate randomly without the need for a central authority, similar to a blockchain-based network, responsible for security and resilience versus attacks. Transactions are recorded in a decentralized manner on each node, ensuring autonomy from third-party authority. The elimination of third-party interference minimizes transaction expenses as well. Unlike a non-sequential information layout, however, blockchain technology allows for a sequential arrangement in which data elements are kept in a chain structure and grow in sequence. Furthermore, the connectivity between public blockchain members ensures that any energy utility may achieve peer-to-peer sharing of information, which facilitates automatic planning. Blockchain technology's basic principles, that is mining, linking, and creating keys, enable legal confirmation of the many sources of power transactions to happen between utilities. When a blockchain is used in the energy sector, delivery to clients of the data of electricity costs and other data may be automated. Self-participation is encouraged by blockchain, which enables transparency of power generation and distribution, as well as adaptable demand-side management systems and real-time price comparison (Mengelkamp et al., 2018). The transparency provided by blockchain technology opens up prospects for prosumers, allowing smart houses to not only produce but also trade energy generated from renewable resources. This approach also allows customers to be more flexible, resulting in a more customer-focused experience. Blockchain technology also ensures anonymity because users are identified by their cryptographic keys instead of their true names. The use of zero-knowledge evidence can also enable anonymity in the blockchain. Aside from the energy markets, the blockchain has applications in the smart grid meter removal process, as shown in Fig. 8.3.

8.1.3.1 Security management

Traditional credit and debit card-based systems necessitate the sharing of credit card details with a third-party, like a bank. The bitcoin revolution promotes decentralization and offers an alternative to dealing with third-party issues. All financial transactions are securely maintained on a global ledger with a cryptocurrency infrastructure. Because ledgers are accessible to all network members, each transaction's validity and consistency can be confirmed easily. Several blockchain-based project plans have been developed to address the challenge of secured amount exchange for energy transactions. The majority of them make use of cryptocurrency to make payment transactions. All payments to be exchanged are verified by the sender with the paying account's secret key. A new electronic cryptocurrency called Energycoin has been developed for power trading. NRGCoin and SolarCoin were built specifically for renewable power exchange in the smart grid system. The node

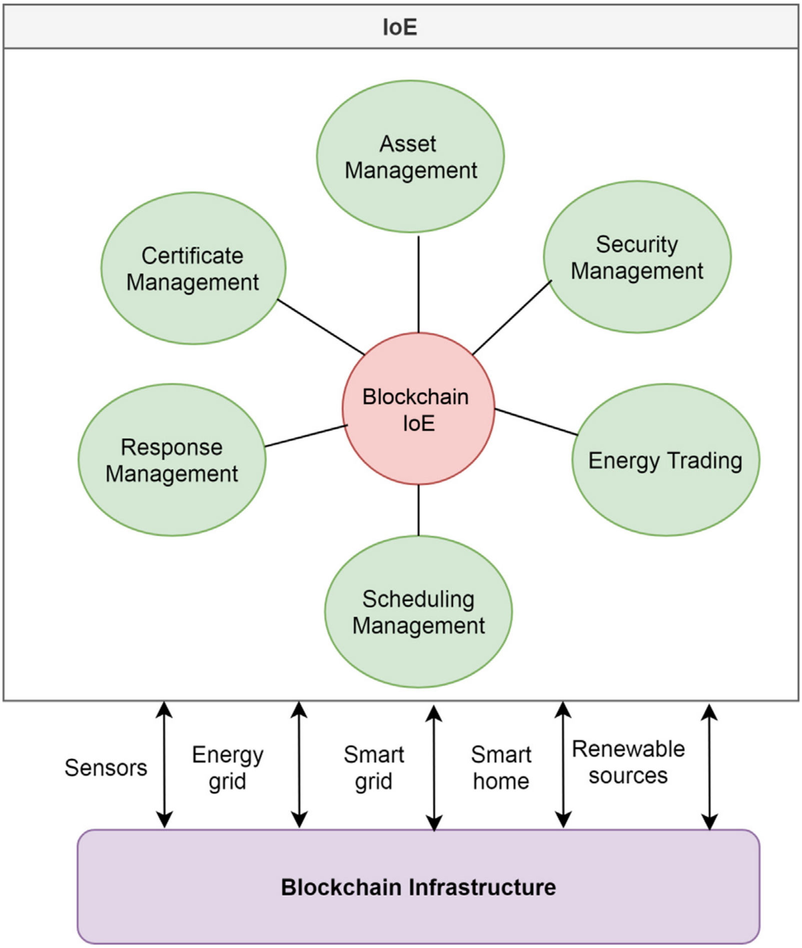

Figure 8.3 Integration of blockchain in internet of energy.

that provides renewable energy technology receives cryptocoins according to the amount of energy produced in NRGCoin and SolarCoin. Secure information sharing, privacy protection, audits, and dependable payments are all achieved through this technique. This plan, though, is not completely decentralized because it includes a provision for the services for auditing and recording the actual identity of peers.

8.1.3.2 Energy trading

Smart grids, microgrids, electric vehicles, payment centers, and authentication centers are all involved in charging or discharging processes. By transmitting bogus data, impersonating others, and charging exorbitant electricity charges, unscrupulous energy market participants might jeopardize the security and privacy of electric mobility. Automobile sensitive data, including vehicle and recharging station identities, charging and discharging times, and vehicle type, must be protected. Another danger for electric vehicle mobility is the promotion of bogus charging services. Three types of attackers may be present during the charging or discharging of electricity-powered vehicles. Large-scale electrical vehicles recharging and discharging can cause power system destabilization. Rather than charging electric vehicles from the grids, charging points give the vehicles the possibility of exchanging a depleted battery for a rechargeable one. It's difficult to trust the grid in terms of battery interchange fairness and respect in such a situation. It's difficult to persuade the grid to be truthful and equitable about the electricity transfer in this situation (Peck & Wagman, 2017). Knowledge regarding battery interchange battery brands, remaining energy, and charging current is maintained in a centralized server in the existing centralized system, making it difficult to assess the system's fairness. In a permissioned blockchain system, a private contract theory for EV charging is suggested to maximize operators' utility. To construct efficient contracts among providers and electric vehicles, a smart contract model is relevant. Specifically, the chosen electric motors and the grid can audit activities in a permissioned blockchain system, and a decentralized byzantine fault tolerant (DBFT) consensus process can be utilized to obtain a shared accord.

8.1.3.3 Scheduling management

The optimal advance scheduling of load strategy is suggested in an electrical power distribution system in order to reduce the power distribution in a system with distributed generation units, which was a major attempt to use the blockchain in the efficient energy management approach. ADMM is a technique for breaking down a complex optimal control issue into smaller, simpler sub-problems. During the fusion process, the blockchain can be connected with ADMM to enable all members of the network to validate progression results of solutions. As a result of its convergent characteristic, ADMM is suited for blockchain implementation.

8.1.3.4 Response management

According to, expected to witness considerable growth is anticipated to increase by more than 25% by 2040, resulting in a supply-demand imbalance. Demand-supply disparity is caused by a lack of finance, social implications, and the long time it takes to produce new electricity. Certain nodes could use more energy than others due to varied energy demands, whereas others encounter power shortages. As a result, it's critical to strike a balance between the generation of electricity and its consumption among various consumers. Response management tries to balance energy requirements with production by planning electric vehicles or dispersed power sources to keep off-peak periods as well as peak periods consistent. Despite delivering significant benefits, demand response techniques have a number of security and compatibility problems. Different protocols have been created by organizations such as NIST and CENELEC to address interoperability difficulties. Blockchain technology, for instance, can address privacy and security concerns in request-response mechanisms. Smart contracts are used to calculate incentives or consequences, identify imbalances, and validate the load management agreement, allowing for an autonomous and flexible system.

8.1.3.5 Certificate management

Blockchains have recently been utilized to construct green energy certifications. Solar panels enable prosumers to produce electricity at home and sell it to power companies. A green certificate verifies that energy was generated using renewable energy sources. The advanced metering system sends the physical record to the centralized agency rather than forwarding it to the centralized agency. Several marketplaces are installed in a decentralized environment to interchange energy and allow consumers and transmission operators to plan for market-based mobility. The certificate of standardization for renewable energy resources improves energy transparency and predictability and gives plant owners more choices. It provides renewable resources, identification, type, and location of energy generation. GaO allows for consistent pricing when selling and acquiring energy. Customers who are ready to profit from renewable energy providers can buy tokenized GaO on a simulated blockchain utilizing Ethereum and smart contracts, where tokens in GaOs are automatically sent among renewable energy providers and customers via blockchain. Commonly, other possible uses of blockchain are to provide protection for authenticated records, which are utilized in the provision of energy certificates to companies.

8.1.4 Energy networking

Due to the scarcity of fossil fuels and the resulting environmental challenges, people are beginning to create renewable energy from renewable sources like solar and wind energy (Rajasekar, Jayapaul et al., 2021). Furthermore, there will still be numerous issues to be resolved in the field of renewable power production. Since these energy supplies are frequently acquired and used in a dispersed rather than a centralized manner, management and trade efficiency are very often weak, and unethical trading is common. A new type of power grid system, the energy network, is used to regulate renewable energy production and optimize the electricity generation system, given it is dependent on power storage computers and the Internet. There are numerous issues in the energy system right now, including generation cost and various security issues induced by centralized administration. Furthermore, as many energy situations shift to a dispersed structure, the previous centralized management paradigm is obviously not possible. The introduction of blockchain technology offers answers to these challenges. The electric power Internet has grown significantly as a result of the advent of distributed ledger technology. It is feasible to create an energy Internet that is truly efficient. The administration efficiency of the new decentralized energy network has been substantially enhanced owing to the deployment of blockchain technology in the areas of management, trade, tracking, as well as other connections in the energy sector. However, as a large number of producers and consumers develop, how and where to manage them becomes a challenge we must address. For instance, when the number of participants in the electricity market grows, it becomes more challenging to keep their huge data. Many issues will arise as a result of storing vast volumes of data in a centrally managed organization. The volume of information will grow as the number of respondents grows, and the accompanying storage cost will rise as well. It will be impossible for other parties to obtain past data if all data is held in one organization, and openness will be tough to enforce. Furthermore, if central organizations are attacked or hacked, all data is at risk of being exposed or deleted. Voltage regulation, on the other hand, is critical in a decentralized power grid since it affects the system's operational stability. However, it appears that dealing with these issues will be challenging for the typical centralized administration technique.

8.1.5 Peer-to-Peer energy supply in grid

The purchases and sales of energy between two or more grid-connected entities are known as peer-to-peer energy trading. Any surplus energy, which is usually in the form of solar energy, could be exchanged and sold to other clients via a secure website. Consumers can choose who they buy energy from and whom they offer it to due to peer-to-peer commodities trading. Surplus solar energy is being transmitted to the grid for a minor feed-in tariff. Nevertheless, as more individuals desire flexibility and control over how their goods are dispersed, this approach is becoming outmoded. Energy is traded on a secure network, which frequently employs blockchain technology. Blockchain is a network technology for processing and storing data, including asset transactions. Renewable energy certificates, which may be exchanged through the blockchain's network, are one example of these assets. Anyone without solar cells can still buy renewable energy from their peers at a fair price, and those who sell their surplus power can sell it for a higher price than they would earn as a grid-connected tariff from their supplier. Energy transmission costs are reduced because energy would not have to be delivered from centrally situated power facilities. According to Genesis Energy, 41.1% of your electricity bill is spent on managing and measuring the poles and cables that carry power from producers to consumers' homes (Rajasekar et al., 2022). Renewable energy can be used to generate electricity, which offers a number of advantages to prosumers, as mentioned above. Power Ledger is a smart contract peer-to-peer sustainable energy trading platform established by an Australian technology startup. The website enables users with solar cells to exchange their excess solar energy with their neighbors in real-time, allowing them to buy and sell renewable-generated energy instantaneously.

8.1.6 Blockchain-based energy trading

Citizens are being pushed to adopt the new notion of peer-to-peer electricity markets as solar energy and energy storage systems become more prevalent. Consumers can gain from using excess power generated by someone using this approach. People can exchange power generated without the use of a middleman if they agree to the terms and conditions (Rajasekar, Premalatha et al., 2021). The transparent transaction benefits both the provider and the recipient. However, it is essential to find unified and efficient peer-to-peer energy trade utilizing the consortium blockchain technology. It avoids the use of a third-party mediator. For fast and efficient energy markets, this peer-to-peer commodities trading model proposes a safe, efficient resource payment approach. Electricity vendors are nodes that have excess energy to sell, whereas energy buyers are units that require energy. The electricity buyer's request will be submitted to a neighboring energy aggregator's network. The server will keep track of energy requests and broadcast them throughout the network in order to locate energy sellers. The energy aggregator works as a broker, in this case, arranging trade between the two nodes. Transmission lines or wireless transmission transfers are used to convey energy from energy suppliers to appropriate energy consumers. The energy coins are sent from the wallet account to the buyer node. This suggested paradigm could encourage the use of renewable energy storage infrastructure. A large-scale decentralized energy trade can be carried out using a trusted, secure approach, though with all participants worried about privacy. However, this collaborative blockchain network is a publicly available digital ledger that verifies and immutably records all energy and financial transactions, even recording the minutest change. All authorized nodes are responsible for maintaining a heterogeneous distributed database.

8.1.7 Green certificate and energy trading

Cars make travel more comfortable, but they also bring with them a slew of issues. Firstly, cars not only speed up the usage of fossil fuels, but they also produce a considerable amount of greenhouse gases, causing environmental issues. But, the widespread adoption of electric vehicles has lowered not only carbon dioxide emissions but also the users' gasoline costs. In addition, it encourages the advancement of renewable energy technology (Velliangiri et al., 2021). However, electric vehicles are not without their share of problems: the rise in the number of electric vehicles has attendant complications, including the installation of charging infrastructure, mode selection, and safety concerns during the charging process. The buildings where charging infrastructure will be installed are quite expensive if centralized administration is used. It's also impractical to expect a single department to oversee such a vast number of electric vehicles. As a result, individuals are exploring techniques to handle distributed EV charging, the majority of which are built on blockchain applications. However, using a distributed charging system necessitates taking into account pricing mechanisms as well as privacy protection during the power transaction process. The disclosure of sensitive private information, such as EV drivers' routes and preferred charging stations, will cause problems for their owners. Electric automobiles may be recharged in a variety of methods, including direct battery replacements at supercharger stations, without having to stop for significant periods of time. However, utilizing this strategy may result in a problem with transaction impartiality. The transaction's fairness will be affected by the different battery models and wear levels. Given this information would be housed on a centralized computer in a traditional centrally administered facility, it follows that fair trading would become more difficult to accommodate. Carbon emission trading is a commercial method for reducing global carbon emissions and encouraging the reduction of greenhouse gas emissions, given its main goal is to reduce the consequences of climate change (Svetec et al., 2019). Companies are assigned greenhouse gas emission quotas by government authorities because various companies have varying levels of ability to manage carbon emissions due to a variety of circumstances. Some businesses struggle to keep their carbon emissions under control, and some have plenty. Underneath the carbon emission exchange mechanism, organizations that do not fulfill the reduction of rated emissions can acquire carbon emission credits from various sources that can overcome the issue of non-fulfillment of objectives. The allotment of carbon emission quotas permits the identification of sources of real emission. The establishment of trade laws and pricing, including regulation, are all issues in the carbon emission trading community right now. Because of the enormous number of enterprises, certifying each energy producer's carbon emission quota would be a huge amount of work in the public sector. Thus, a green certificate, which is a digital certificate issued by a government body to businesses that generate power using renewable energy, can be sold by these businesses, which lightens the burden on the government. The use of blockchain technology in an economical operational system ensures that energy asset transactions are traceable. Producers and consumers can subsidize sustainable energy producers and promote the development of renewable energy by exchanging GoOs. GoOs is a type of green certificate as well.

8.1.8 Characteristics of blockchain in energy trading

Blockchain technology is mostly utilized in distributed management settings to make the preservation of users' data possible, as well as to improve data security and privacy. It can also be used to manage the grid's decentralized infrastructure. In peer-to-peer trade, blockchain can help price, control supply and demand, and assure accountability, security, and user privacy (Teufel et al., 2019). When it comes to EVs, blockchain is primarily employed for paying charging prices. The price can sometimes be determined through bidding and other times by a consensus mechanism that reacts to the market situation automatically. Blockchain technology is primarily employed in carbon emission pricing and green certificate exchange to provide accountability and data confidentiality during the trading system. Because it fits the needs of a decentralized power system with the following qualities, blockchain has widespread use in the energy industry. The characteristics of using blockchain in energy trading are given below:

1. Transparency

   The blockchain's data is synchronized across all nodes, allowing any node to access all transaction information, maintaining transaction transparency. This will enhance transparency in decentralized energy transactions and increase energy trading transparency.

2. Anonymity

   When customers engage in decentralized energy exchange, this feature can assist in preserving their privacy.
3. Decentralization

   This feature of blockchain complies with the criteria of a distributed energy system in terms of decentralized user management and data cloud processing, reducing management costs, and increasing data security.
4. Security

   The decentralized storage design of blockchain makes it harder to have a point of failure because each node might have a comprehensive copy of the entire database. As a result, an attacker cannot take control of the entire database by assaulting or managing a single node. As a result, network security is improved. When used with decentralized energy networks, it also improves the security of consumer information.
5. Democracy

   Through the use of consensus mechanisms in blockchains, transaction choices are more transparent. Because each participating node becomes a manager under the blockchain consensus method, there is no need to be concerned about corruption. Energy management becomes more democratic and effective as a result. Because of the various qualities of the blockchain, like secrecy, decentralization, and anonymity combined with the requirement of the distributed electricity market, its use in the energy field will grow more and more widespread, and the essential technologies will mature. However, there are several issues or hurdles that we must address when applying them to the energy sector.

   Issues such as government interference and legal oversight will arise as a result of adopting blockchain technology for the energy industry. There are more cases where blockchain technologies in the energy sector are important to examine, in addition to potential solutions to the above concerns. The right consensus mechanism should be chosen and improved to prevent high costs in the implementation of the consensus mechanism. Real-time information updates based on the blockchain will aid in the exchange of information between the different nodes and drastically reduce supply system wastage. There are numerous roles engaged in the process of transportation systems, and there are activities and contests with them in the field of power transportation.

8.1.9 Efficient blockchain model for energy utility

Utilities supply energy to customers based on their needs. Residents also generate energy, which they and other residents consume. The data of utilities and consumers is safely stored on a blockchain. Authorized users can analyze and access the data (Tsao & Thanh, 2021). The efficient blockchain framework for energy utility based on smart grid is shown in Fig. 8.4. Smart Grid covers power generation, distribution, and administration. Cloud-based multi-dimensional delivering services, systems, and blockchain-based distributed smart contract payment systems are being used. The main function of this entire framework is a rapid storage and verification infrastructure. Our main goal is to improve smart contracts so that dynamic price per unit calculations can be made. Energy users and producers are included in the SG area, and data is exchanged among SG and blockchain. The cloud is being used to store data indefinitely. Hyperledger's elements include smart contracts,

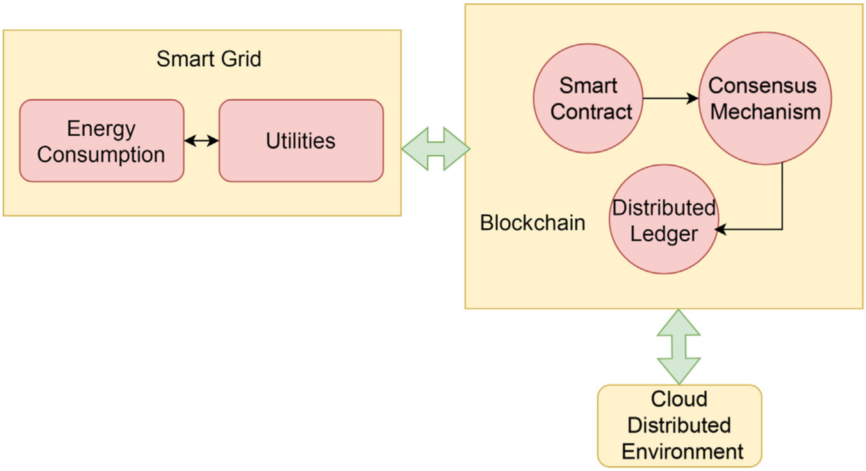

Figure 8.4 Smart grid energy utility model.

consensus, and a ledger (Wang & Su, 2020). A smart contract ensures that the transactions between the producer and the consumer are legal and that the transactional data is recorded in the ledger. The utility creates and distributes electricity to its customers. The bank is used to exchange money for coins. Every citizen is a consumer, and only a handful is both consumers and producers. Residents who are producers generate RER and sell it to other neighbors. When a household produces an extra unit of power, the information is updated. The total amount of electricity consumed changes every time. When a resident receives electricity in return for coins, the account of coins is also monitored and updated.

A single utility cannot meet the needs of all citizens. As a result, producers must sell any excess electricity to other users. If the price of power is set, and manufacturers can only offer this for the same price with which it was produced, producers will get greedy and store all of the electricity generated for them. If the producer chooses a high selling price for power in a bidding procedure, it becomes simple for the customer to purchase electricity from the utilities rather than from other residents at a high cost. Utility demand is increasing, yet producers are not driven to supply electricity. Hyperledger is a project that aims to enhance blockchain technology (Wu & Tran, 2018). In December 2015, the Linux Foundation established the platform. It is the result of collaboration between thirty foundations members, including professionals from finance, banking, IoT, supply chains, production, and innovation. Hyperledger Composer is a set of tools for constructing smart blockchain networks, including smart contract and blockchain-based creation, management, and testing. Participants/parties who are directly involved with the exchanges are interconnected on a hyperledger-based infrastructure. The ledger is modified and updated when electricity and money are exchanged. As a result, privacy and secrecy are preserved. Our challenge is solved using the Hyperledger Fabric framework. It offers assistance for distributed ledgers. It has elements that help with consensus and membership operations. While the participant's enrollment is validated by the membership facilities, the transaction's validity is ensured by the consensus mechanism. As a result, the participant's legitimacy is preserved, and security is provided. Concurrency control is used by Hyperledger Fabric to boost throughput by assistance in completing in parallel. Fabric's features make it a massively scalable platform, particularly for blockchain systems. The programmable logic that produces new regulations and facts that are recorded in the ledger is defined by the smart contract. Smart contracts are computer programs that give an output from pre-defined terms and conditions, or inputs, that are determined by both customers and producers. Those contracts outlined a corporate strategy. These business paradigms manage relationships between consumers and producers.

8.1.10 Benefits of using blockchain in the energy sector

The energy sector plays an important role in its being transformed by distributed ledger technology or blockchain. Innovations such as rooftop solar, electric cars, and smart metering have continually stimulated the energy market. With its smart contracts and network interoperability, the Enterprise Ethereum blockchain currently promotes itself as the next key technology to stimulate growth in the energy industry. By monitoring the chain of custody for system components, the distributed ledger technique offers a great ability to increase efficiencies for utility companies (Zhang et al., 2018). Blockchain provides special possibilities for renewable energy distribution in addition to provenance monitoring. Enterprise Ethereum solutions have the potential to improve traditional energy industries like oil and gas. Blockchain technology has the potential to improve complex systems with various actors. The following are the primary advantages of blockchain in the electricity sector:

1. Cost savings
2. Ecological sustainability
3. Higher visibility for stakeholders.

Consumers can benefit from improved efficiency and production over their energy sources thanks to blockchain technology. A safe and real-time updating of energy consumption data is also provided by an immutable ledger. Market prices, variable costs, energy law compliance, and fuel costs are all examples of different sorts of energy statistics. Electric power companies are vast, sophisticated businesses that generate electricity from power plants, solar farms, and other sources. In comparison to financial institutions or the banking business, utility companies do not interact with others. The capacity of a blockchain technology framework to trace and verify supply chains could prevent massive waste. Furthermore, a platform that makes use of intelligent legal contracts can save time, power, and money for all of the energy businesses involved. An immutable database can aid in the management and tracking of data required at all phases of energy production (Zhao et al., 2021). By ensuring that nothing will be forgotten or destroyed, the technology helps save time and money. The new, disruptive electrical network is evolving at the same time as blockchain-based networks, and the two technologies have symbiotic relationships: blockchain may be a significant facilitator of the electricity network, allowing distributed electricity generation and an operating network having a local decentralized system. The combination of these two technologies might open up a slew of profitable prospects for companies working to solve these energy problems and increase renewable energy consumption.

8.1.11 Chapter summary

Blockchain could provide a secure, low-cost mechanism to record and confirm operating and financial transactions along a decentralized system with no central authority. Sensors and modern communications are used by customers and suppliers to collect the required data and forecast demand and supply. The present energy sector began changing towards distributed and decentralized approaches with the utilization of smart grid energy utilities like electric vehicles, smart grid, and vehicle-to-grid technologies. The capacity of a blockchain technology framework to trace and verify supply chains could prevent massive waste. Furthermore, a platform that makes use of intelligent legal contracts can save time, energy, and money for all of the energy businesses involved. An immutable database can aid in the management and tracking of data required at all phases of energy production. The combination of these two technologies might open up a slew of profitable prospects for companies working to solve these energy problems and increase renewable energy consumption.

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