A Comprehensive Analysis of Blockchain-based Cryptocurrency Mining Impact on Energy Consumption

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***Abstract*—Blockchain already has gained popularity due to its highly secured network and same time enormous computational power consumption has become an undifferentiated debate among the users. A Blockchain network is reliable, secure, transparent, and immutable where the transactions cannot be reversed between sender and receiver. Blockchain technology is not only used for mining cryptocurrency, it has other applications in different sectors like agriculture, education, insurance, etc., but the noticeable concern is still energy consumption. On the other hand, there is a significant impact on the environment due to the use of excessive energy for mining cryptocurrency which releases more carbon dioxide (CO_2) in nature. The Proof-of-Work (PoW) algorithm is used for mining 'Bitcoin' which is consumed enormous computational power. However, an alternative solution like Proof-of-Stake (PoS) consensus protocol has been proposed to use instead of the Proof-of-Work algorithm for mining cryptocurrencies which is capable to reduce the significant amount of energy consumption. Not only that, but the use of renewable energy can also be an alternate option to use the Proof-of-Work algorithm for mining cryptocurrencies which is environment friendly. This paper aims to highlight blockchain technology, the energy consumption and impact on the environment, energy reducing method by using PoS consensus protocol instead of using the PoW algorithm, and discussion with some recommendations.**

Keywords*—Blockchain; cryptocurrency; bitcoin; Proof-of-Work (PoW); Proof-of-Stake (PoS)

I. Introduction

Blockchain already has gained popularity due to its highly secured network. Bitcoin is the first cryptocurrency that was introduced by the pseudonymous name Satoshi Nakamoto [1]. Blockchain technology was used to develop this cryptocurrency. Bitcoin is also called digital currency which is used for transacting the currencies between peer-to-peer (P2P) into the blockchain secured network without the intervention of a third part intermediator [2-3].

A Blockchain network is reliable, secure, transparent, and immutable where the transactions cannot be reversed between sender and receiver [4]. Another strong security feature cryptographic hashing algorithm is used to maintain the data integrity by applying the encryption and decryption method this algorithm is also used for joining the blocks in chronological order and forming a chain [5-6]. Decentralization of data and storing the same in all existing nodes in the network is an important feature to provide data backup [7]. The distributed ledger is used for keeping all the information in different geographical locations where every user is capable to view the data [8]. Proof-of-Work (PoW) algorithm is a very strong, secured, and powerful mechanism that is used for mining a new block into the blockchain network and keeping the transaction records in this block permanently [9-10]. In the last couple of years, a few numbers of a consortium like r3 Corda, Hyperledger Fabric, Ethereum, etc. have been formed in the banking sectors where some of them are already doing the transactions for cross-border payment among themselves on a pilot basis [11-13]. The not only banking sector, other sectors like healthcare, education, insurance, agriculture, etc. are highly considered for keeping their information in this blockchain network with the consideration of security and transparency [14].

Though blockchain technology has several advantages, some significant challenges need to be addressed by the implementation. Power consumption is one of the major concerns for people across the globe [15]. Proof-of-Work is the powerful algorithm of blockchain technology to mine a new block into the blockchain network which consumes the maximum amount of power [16]. Due to the enormous consumption of power, there is a huge impact on the environment due to the emission of carbon dioxide. Maximum power generates from fossil fuels around the world which help to produce carbon dioxide and pollute the environment simultaneously [17-18]. This paper will briefly discuss the background and architecture of blockchain in section II, cryptocurrency mining procedure by using the PoW mechanism in section III, methods of reducing the impact of producing cryptocurrency mining power and other impacts as well in section IV, and finally, the paper will be concluded by section 5.

II. Blockchain Background and Architecture

First, the blockchain concept was introduced in 1990. In 1992 the trusted data tempering protocol was ensured in the format of a chain that guarantees the privacy of data in the form of the integrity of the records [19]. Fig. 1 shows the history of blockchain technology.

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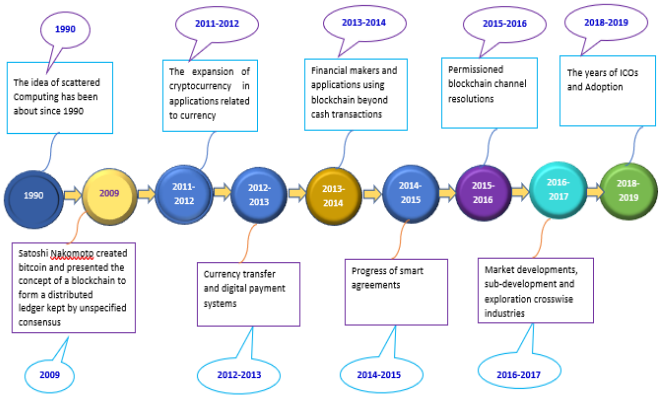

Fig. 1. A Brief Blockchain History [20].

The pseudonymous name Satoshi Nakamoto first introduced a new cryptocurrency called Bitcoin in 2009 for the peer-to-peer transaction into the blockchain network [1]. Gradually blockchain technology was becoming popular and more cryptocurrencies like Litecoin, Namecoin, and PPCoin were founded from 2011 to 2012 [21]. Some other remarkable cryptocurrencies Ripple, Dogecoin, and Stellar were introduced in the year 2012-2014 [22-23]. Another emerging cryptocurrency called Ethereum was came-up in the market by using a famous Ethereum blockchain network which was launched in 2015 [13]. Nowadays, there is a significant number of cryptocurrencies already have been introduced with their network infrastructures which are shown in Fig. 2. The maximum use of this blockchain technology and cryptocurrencies in the financial sectors. With consideration of the security, transparency, and reliability of this network, some other sectors like health care, insurance, education, energy, and agriculture have already started to implement blockchain-based applications in their companies in different countries around the world.

A. Blockchain Architecture

The architecture of blockchain is completely different from a traditional centralized database management system where the information is stored digitally in all the connected nodes in a decentralized manner rather than a centralized version [25]. All the blocks in the blockchain network are connected through a chain that a cryptographic algorithm uses to maintain security [26]. However, the block maintains three different parts data section, a hash of the present block, and the hash of the previous block. The useability of the blockchain network depends on the nature of the business aspect. The cryptocurrency blockchain keeps the transactional records in the nodes. Every time hash value will be changed if any new data will add or amended to the data in the blocks of the network [27]. The hash value is generated by using the hash function and it converts the data in a fixed format like 32 bits, 64 bits, 128 bits, 256 bits whatever may be the size of the input data [28]. It depends on the nature of the hash function. The previous block hash connects to the next block to form a blockchain network. The initial block is called the genesis block where the hash value is 0 [29]. For example, in Fig. 3, a simple blockchain has been presented where the genesis block contains the 0 (zero) hash value for the initial, 7A4RFGY8 is the present block hash for block 1, 8GJI7RGY represents the block 2 hash, and so on where all the blocks have connected each other cryptographically. Due to this complex format, manipulation of records is almost impossible. To compromise any bit of information in the network, all the consequence hash values need to be changed in the entire network, and at least 51% of nodes to be agreed to make any amendment [30]. The distributed ledger is used to make transaction into the blockchain network which is an immutable ledger and help to resist the temperament of the data in the block [31].

B. Data Signing and Verification Process

The data signing and verification process is shown in Fig. 4. The plain text format data pass into the hash function and convert the data as the fixed hash format. The hash values are encrypted by using the private key of the sender and converted as a digital signature [32]. This digital signature is attached to the data and creates digitally signed data which send to the receiver.

On the other hand, after receiving the digitally signed data by the receiver, the receiver verifies the originality of the data. First, the receiver decrypts the encrypted data by using the signatory's public key which helps to find the hash value [33]. Second, the receiver then passes the plain text data sent by the sender will pass through the hash function and get the hash value. The receiver will then check the integrity and originality of the data by matching both hash values [34].

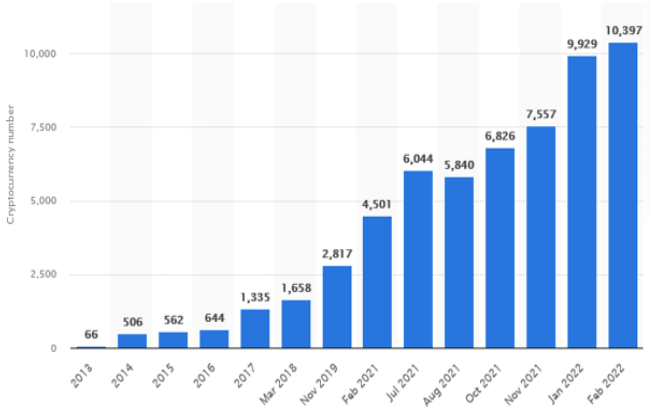

Fig. 2. Cryptocurrency Statistics [24].

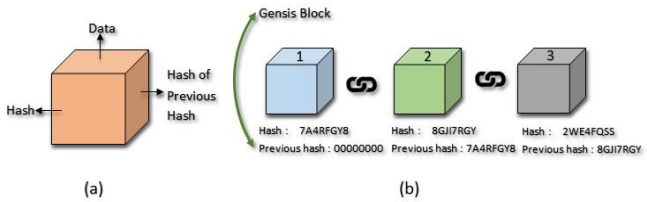

Fig. 3. Blockchain Structure.

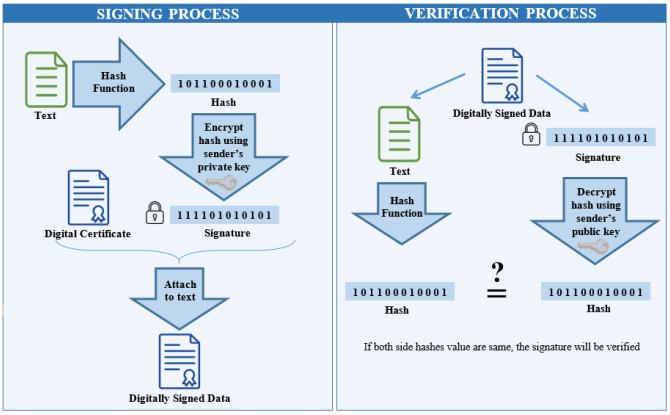

Fig. 4. Digital Data Certification Process in the Blockchain.

C. Transaction Process into the Blockchain Network

There are a few steps that must follow for adding a transaction into the blockchain network which are shown in Fig. 5. Before transacting into the network, the authentication and authorization process needs to be done by using cryptographic keys and proof of work simultaneously [35]. As shown in Fig. 5, the transaction process describes the popular bitcoin network which runs in a public network where anyone can participate. Initially, the transaction initiator sends the transaction request into the public bitcoin network for authentication and adding the data into the network. The transaction requests all the nodes into the network for verification for the same [36]. Once the transaction is validated by the nodes, the block is then added to the blockchain network, and all the participants' nodes are rewarded by bitcoin for participating for proof of work [37]. After that, the transaction will be completed by updating the blockchain network. Private and public keys are used to validate the transactions where the private key is used for digitally signing the data and the public key is used for decrypting the data at the receiver end [38-39]. On the other hand, authorization is required to add the data into the block through a consensus mechanism which means the majority nodes need to be agreed to complete the transaction [40].

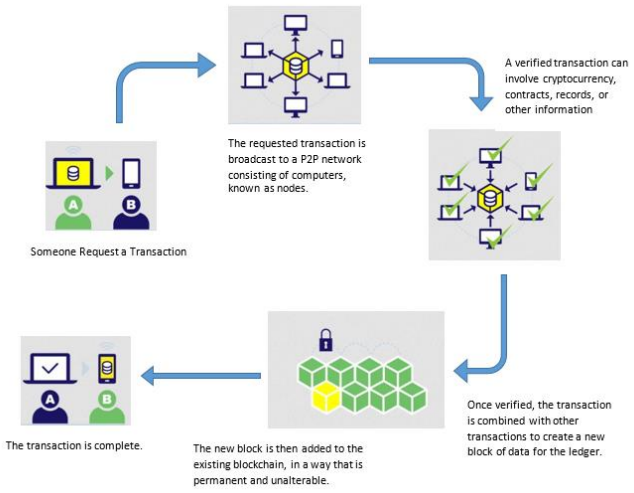

Fig. 5. Transaction Process in the Blockchain Network.

III. Energy Consumption and Impact of Blockchain

Though blockchain is a highly secured platform, energy consumption becomes very high especially when the mining process has occurred which is a big concern in the industry [41-42]. The validation for proof of work algorithm is a complex as well as trial and error process for matching with hash value [43]. For example, an average of ten minutes is required to mine a new block for the bitcoin miners. In terms of data security and integrity, it is highly recommended for using this technology where energy consumption is a big concern for different entities [44].

In an article has been published by Raynor de Best in February 2022, the total number of cryptocurrencies more than 10,000 shown in Fig. 2 which have been drastically increased from 2013 [45]. However, all these digital currencies are not active in the market. Different algorithms are used for mining these cryptocurrencies. Among the plenty of digital currencies, bitcoin is the most popular and useable cryptocurrency across the globe which consume an exorbitant amount of energy for mining bitcoin. There is an article written by Eugene Kim in September 2021 in business insider mentioned that approximately 0.5% electricity of total global electricity used for mining the bitcoin which is approximately more than 7 (seven) times the energy consumption by google per year [46]. The energy consumption for mining the bitcoin from 2017 to 2021 is presented in Table I, the electricity consumption rate has been significantly increased every year, and this consumption in the year 2021 is nearly 6 times that of 2017. From Table I, the number of bitcoins mining gradually decreased from 2017 to 2022. On the other hand, the usage of electricity for mining bitcoin gradually increased over the same period, and finally, bitcoin mining costs were increased.

On the other hand, the Ethereum blockchain uses much less electricity than the bitcoin blockchain for mining Ether tokens which is shown in Table II [47]. As per Table II, the total electricity of 145.39 TWh has been used to mine approximately 59.5 million ethers whereas 480.82 TWh electricity has been used to mine 2.83 million bitcoins only which is shown in Table I. The average mining cost for one bitcoin is USD 19,229, whereas the average mining cost for one ether is USD 217.52 only which is shown in Table III.

An article was published in "The New York Times" in September 2021, approximately 91-terawatt hours of electricity is consumed annually to mine bitcoin which is more than the used by Finland where the population is about 5.5 million [52]. The bitcoin mining electricity consumption was higher than the electricity consumption by Ireland in 2017 [53]. Bitcoin uses more electricity annually than Argentina [54]. on the other hand, the Cambridge University researchers said the bitcoin uses approximately 121.6 terawatt-hours (TWh) which is more than the electricity usage by Argentina (121TWh), 108.8 TWh used by Netherland, and the United Arab Emirates uses 113.20 TWh annually [55] that represent in Fig. 6. China is the highest electricity consumer for mining bitcoin in the world which is 71.70% and the remaining balance is approximately 28.3% uses by the rest of the world whereas USA and Russia are second and third which is shown in Fig. 7 [56]. David Vetter published an article in Forbes where he predicted that by 2024

China alone will use more power for mining cryptocurrency than Italy uses electricity annually [57].

TABLE I. ELECTRICITY CONSUMPTION FOR MINING BITCOIN FROM JAN 2017 TO OCT 2021

Year	Electricity uses by Bitcoin mining (TWh) [47]	Electricity uses growth (%)	No of Bitcoin mining ('000) [48]	Per Bitcoin electricity consumption (KWh)	Avg. retail electricity cost/KWh in USA (USD) [49]	Per Bitcoin mining cost (USD)
2017	36.68		700	52,400	0.1048	5,492
2018	45.81	24.89	680	67,367	0.1053	7,094
2019	73.12	59.62	680	107,529	0.1054	11,334
2020	77.78	6.37	460	114,382	0.1059	12,113
2021	177.43	128.12	330	537,667	0.1118	60,111
Total	410.82		2,830			

TABLE II. ELECTRICITY CONSUMPTION FOR MINING ETHER FROM MAY 2017 TO DEC 2021

Year	Electricity uses by Ethereum (TWh) [50]	Electricity uses growth (%)	Approx. no of Ether mining ('000) [51]	Per Ether electricity consumption (KWh)	Avg. retail electricity cost/KWh in USA (USD) [49]	Per Ethereum mining cost (USD)
2017	9.56		9,000	1062	0.1048	111.30
2018	9.63	0.73	8,000	1204	0.1053	126.78
2019	8.14	15.47	10,000	814	0.1054	85.80
2020	14.64	79.85	15,000	976	0.1059	103.36
2021	103.42	606.42	17,500	5910	0.1118	660.34
Total	145.39		59,500			

TABLE III. MINING COST COMPARISON BETWEEN BITCOIN AND ETHER

Year	Per unit of Bitcoin mining cost (USD)	Ave. Bitcoin mining cost (USD)	Per unit of Ether mining cost (USD)	Ave. Ether mining cost (USD)
2017	5,492		111.30	
2018	7,094		126.78	
2019	11,334	19,229	85.80	217.52
2020	12,113		103.36	
2021	60,111		660.34	

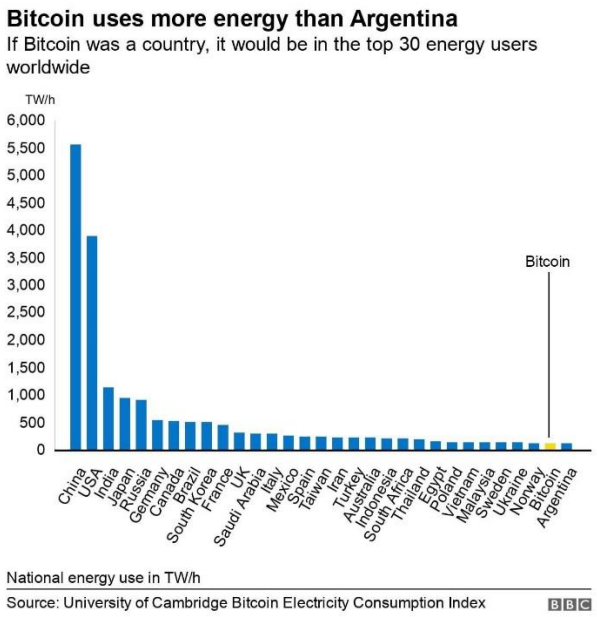

Fig. 6. Bitcoin Mining Power Consumption Globally.

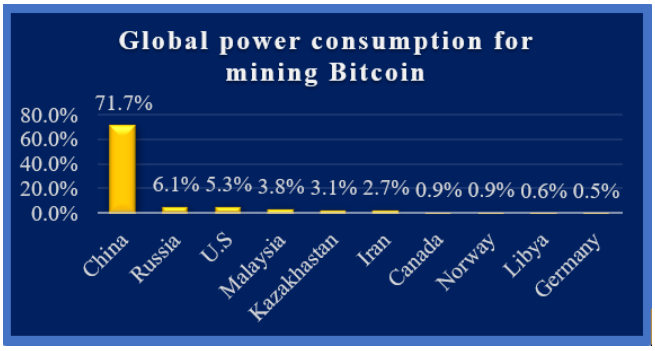

Fig. 7. Country-Wise Monthly Average Bitcoin Mining Computing Power.

However, the electricity consumption has been abruptly increased for mining bitcoin which is 177.43 TWh in 2021 as per Table I. Bitcoin mining needs 17MJ (megajoules) of power to generate an equivalent $1 amount of bitcoin whereas gold mining takes 5MJ to produce an equivalent $1 amount of gold [58]. On the other hand, there is a huge impact on the environment due to excessive use of electricity for mining bitcoin which releases more carbon dioxide (CO_2) into nature. Since the long increase of CO_2 in the environment is one of the big concerns in the world, cryptocurrency mining is increasing day by day which might be a severe disaster for the environment [59-60]. It is not only helping to increase CO_2 in nature, and it helps for rising temperature in the environment [61]. Table IV represents the fossil CO_2 emission from 2017 to 2022 and it shows that the CO_2 emission was 0.16% in the year 2017 and it sharply increased to 0.80% in 2021 which is alarming for the environment in the future.

On the other hand, CO_2 emission by Ether is approximately half of the bitcoin mining, which is shown in Table V, where the CO_2 emission is 0.46% in 2021. The combined impact of emission CO_2 has become noticeable for the environment due to generate bitcoin and ether where 0.99 Giga Tone (Gt) extra

CO_2 has been added in the nature shown in Table V. Bitcoin and Ether are not only the cryptocurrencies in the world, there are more than 10 thousand cryptocurrencies have been created by different companies though all of them are not active commercially, it will be extremely alarming for the nature in future if all the cryptocurrencies will go for commercial production.

TABLE IV. CARBON DIOXIDE EMISSION FOR MINING OF BITCOIN

Year	Fossil CO_2 emission in nature (Gt) [62]	Global electricity consumption (TWh)	Electricity consumption by bitcoin mining (TWh)	Fossil CO2 emission by bitcoin mining (Gt)	Fossil CO_2 emission by bitcoin mining (%)
2017	36.40	23,150	36.68	0.06	0.16
2018	34.80	22,153	45.81	0.07	0.21
2019	36.70	23,432	73.12	0.11	0.31
2020	36.60	23,176	77.78	0.12	0.34
2021	35.90	22,270	177.43	0.29	0.80
Total	180.40	114,181	410.82	0.65	

TABLE V. CARBON DIOXIDE EMISSION FOR MINING OF ETHER

Year	Fossil CO_2 emission in nature (Gt) [59]	Global electricity consumption (TWh)	Electricity consumption by Ether mining (TWh)	Fossil CO_2 emission by Ether mining (Gt)	Fossil CO_2 emission by Ether mining (%)	Fossil CO_2 emission by Bitcoin and Ether mining (Gt)
2017	36.40	23,150	9.56	0.02	0.04	0.08
2018	34.80	22,153	9.63	0.02	0.04	0.09
2019	36.70	23,432	8.14	0.01	0.03	0.12
2020	36.60	23,176	14.64	0.12	0.06	0.24
2021	35.90	22,270	103.42	0.17	0.46	0.46
Total	180.40	114,181	145.39	0.34		0.99

Fig. 8 represents the future prediction of electricity need for mining the bitcoin and Ether only which is drawn based on the bitcoin and Ether mining data from 2017 to 2021 where the electricity consumption will be increased by approximately more than 300 TWh in the year 2023 which can be higher than the annual consumption of many countries in the world.

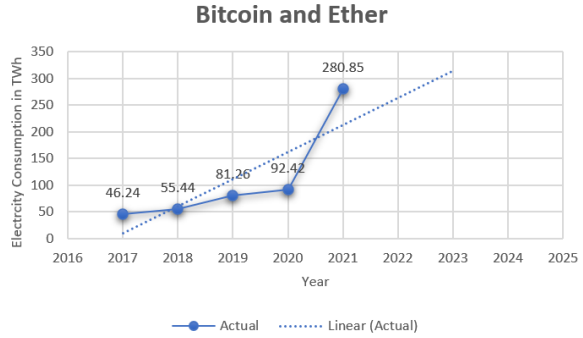

Fig. 8. Prediction of Electricity Consumption for Mining Bitcoin.

However, the proof-of-work algorithm is used to solve a complex mathematical problem for mining the bitcoin is the main concern for consumption of high energy [63-64]. It is an open public platform, and any participant can join the network and can be awarded by solving the mathematical puzzle. The PoW consensus algorithm is used to validate the transaction as well as generate the new blocks into the blockchain network [65-66]. The participants in the blockchain network send the transaction and all the transactions are gathered using the distributed ledger in the blocks through the validation process [67]. Though millions of participants compete to solve the puzzle, only a single participant will be declared a winner who can solve the cryptographic puzzle first, and this message will convey to all the users in the network [68]. So, the bitcoin mining power consumption is not so high concerning the winner [69]. But the participants those are not succeeded to solve the puzzle, their computers also use their power for the same which ultimately enormous amount of energy. The bitcoin mining process is shown in Fig. 9 where all the participants try to solve the complex mathematical puzzle to find out the nonce that can be matched with the target value [70]. To solve the mathematical puzzle, a large amount of computational power is required which depends on the issues are i) Hash function, ii) Integer factorization, and iii) Guided Tour Puzzle protocol.

- Hash Function: SHA-256 cryptographic hashing function is used for mining bitcoin where chunk amount data is used as input and bring it down the value in fixed format 256 bits [71]. Whatever the input, the out-hash value will be the same which fixes 256 bits or 64 bits hexadecimal value [72]. There is no simple way to get the hash value which depends on the lots of input data to needs to be used as the trial basis and it comes consumes huge computational power.
- Integer Factorial: It is used to secure the public key encryption process [73]. It is the way to represent the present whole number of the multiplication of two other numbers [74].
- Guided Tour Puzzle protocol: It works to protect the Denial of Service (DoS) attach to the blockchain network [75]. It also insists to focus on the nodes to compute the memory-bound puzzle which helps the users to use the abandoned computational power [76].

Presently, the blockchain network for bitcoin is growing faster, the users are facing more difficulties to solve the cryptographic puzzle and the algorithm needs more power to solve the same which tends to use more power for mining bitcoin.

Earlier, only a CPU was used for mining the bitcoin which is very slow and consumed more power to generate the bitcoin. To minimize the mining cost, special hardware called GPU is used for the same purpose. GPU is around 100 times faster than traditional CPU. Application Specific Integrated Circuit (ASIC) is another option that is also father than GPU, CPU, and FPGA which is shown in Fig. 10.

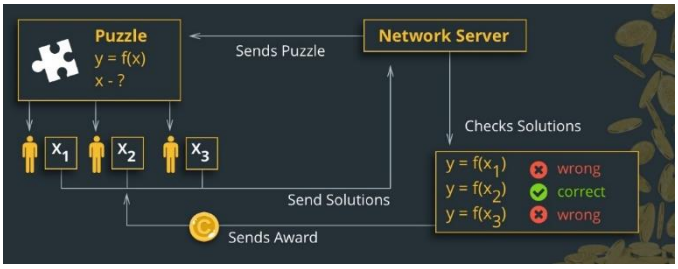

Fig. 9. Bitcoin Mining Process [77].

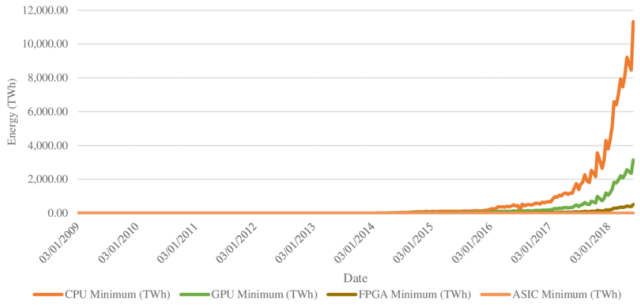

Fig. 10. Power Consumption by CPU, GPU, FPGA, ASIC [78].

IV. Energy Reducing Methods in Blockchain

Several layers consume the power for mining cryptocurrency, but the enormous power is used by the Proof-of-Work hashing algorithm. Here we have discussed the three methods A. Proof-of-Stake (Pos), B. Delegated Proof-of-Stake (DPoS), and C. Use of renewable energy. Method A and B will contribute to saving more energy for mining the cryptocurrency especially bitcoin which is used as an example. On the other hand, if the cryptocurrency network owners do not want to change the PoW algorithm, method iii) can be the alternative solution that is not capable to save energy for mining bitcoin, but it is environment friendly.

A. Proof-of-Stake (PoS)

PoS is a consensus algorithm that is the improved version of the PoW algorithm that may reduce the 99.5% power consumption for mining the cryptocurrency [79]. This algorithm does not depend on competition to generate a suitable hash among the users. The protocol determines the selector based on the ownership of the coin supply which replace the computational power and the transaction validation process will be done by this stakeholder. In Fig. 11, there is no miner is needed to validate the transaction. The participant's 33% stakeholder will be the validator of the transaction due to holding the maximum amount of stake in the network. The validators will not be rewarded for block validation and get the transaction fees only. Due to the single validator concept, the energy consumption is very low and there is no wastage of power. On the other hand, a successful miner for mining the bitcoin will be the gainer, the use of power by other miners should be considered a wastage of power. This wastage of power generates an excessive amount of carbon dioxide in the earth. If the PoS consensus algorithm was used instead of PoW for mining the bitcoin, a significant amount of power could be saved, and the CO_2 emission cloud is insignificant. As per Tables VI and VII, the carbon dioxide emission could be minimized by 179.75 Giga tones and 180.06 Giga tones for mining bitcoin and Ether respectively from the year 2017 to 2021 by using the PoS algorithm instead of the PoW algorithm. So, the PoS consensus algorithm is much more efficient and cost-effective for mining bitcoin and ether, and at the same time, it is environmentally friendly as well [80].

TABLE VI. Impact of PoS on Electricity and CO_2 to Mine Bitcoin

Year	Electricity consumption for mining Bitcoin (TWh) using PoW	Electricity Requirement for mining Bitcoin (TWh) using PoS	Electricity saves (99.5%) by using PoS (TWh)	CO_2 emission in nature (Gt) using PoW	CO_2 emission for mining Bitcoin (Gt) using PoS	CO_2 emission saving by using PoS (Gt)	CO_2 emission saving (%) by using PoS
2017	36.68	0.18	36.50	36.40	0.06	36.34	99.84
2018	45.81	0.23	45.58	34.80	0.07	34.73	99.80
2019	73.12	0.37	72.75	36.70	0.11	36.59	99.70
2020	77.78	0.39	77.39	36.60	0.12	36.48	99.67
2021	177.43	0.89	176.54	35.90	0.29	35.61	99.19
Total	410.82	2.05	408.77	180.4	0.65	179.75	99.64

TABLE VII. Impact of PoS on Electricity and CO_2 to Mine Ether

Year	Electricity consumption for mining Ether (TWh) using PoW	Electricity Requirement for mining Ether (TWh) using PoS	Electricity saves (99.5%) by using PoS (TWh)	CO_2 emission in nature (Gt) using PoW	CO_2 emission for mining Ether (Gt) using PoS	CO_2 emission saves by using PoS (Gt)	CO_2 emission saving (%) by using PoS
2017	9.56	0.05	9.51	36.40	0.02	36.37	99.95
2018	9.63	0.05	9.58	34.80	0.02	34.73	99.94
2019	8.14	0.04	8.10	36.70	0.01	36.62	99.97
2020	14.64	0.07	14.57	36.60	0.12	36.50	99.67
2021	103.42	0.52	102.90	35.90	0.17	35.73	99.53
Total	145.39	0.73	144.66	180.4	0.34	180.06	99.81

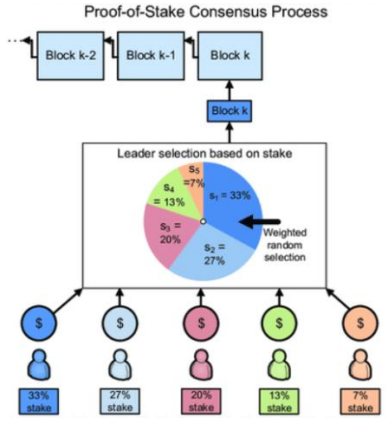

Fig. 11. Proof-of-Stake Consensus [80].

B. Delegated Proof-of-Stake (DPoS)

There is another protocol called Delegated Proof-of Work (DPoS) is the evolution of the PoS algorithm where the users are required to keep in stake their coins for getting the validation power for the transaction. The users of the blockchain network need to provide the votes and elect the delegate for validating the next available block. A maximum of 20 to 100 delegates can be chosen to validate the new block and the delegates for one block cannot be the delegate for the next block where the delegates will be eligible to receive the transaction fees from that validated block [81]. In terms of power consumption, DPoS is almost the same as the PoS algorithm which can be a good choice to use this protocol instead of the PoW algorithm for mining bitcoin or other cryptocurrencies. A comparison among PoW, PoS, and DPoS has been provided in Table VIII.

TABLE VIII. COMPARISON OF POW, POS, AND DPOS

PoW	**PoS**	**DPoS**
i. Number of participants becomes very high for mining cryptocurrency. ii. Energy consumption volume is very high. iii. Transaction speed is slower than PoS and DPoS. iv. Transaction validation method is very comparative for receiving the reward	i. Number of the participant is one and depends on the stake of the coin. ii. No extra power is required except the single computer power. iii. Transaction speed is very higher than PoW. iv. Competition for validation of transaction is not required due to a single selected validator.	i. Number of participants is limited to between 10 to 100. ii. Less energy consumption than PoW iii. Transaction speed is very higher than PoW and PoS iv. Competition for validation of transaction is not required due to selected validators.

C. Use of Renewable Energy

On the other hand, renewable energy may be the alternative option for mining cryptocurrency by using the same PoW algorithm. Though it will not save the electricity consumption rate, it will help to reduce the environmental pollution where the carbon dioxide emission will be zero. The largest bitcoin mining location in Dalian, China where the hash rate is 360,000 TH is used for mining 750 bitcoin every month and the average monthly cost is $1,170,000, and the second-highest mining location in Moscow, Russia where the hash rate is used 38PH for mining 600 bitcoins in every month and the monthly cost is $120,000 [82].

Renewable energy sources are preferable rather than non-renewable energy sources for mining cryptocurrency whereas IBM and Intel also prefer to use green energy for blockchain-based cryptocurrency transactions. Renewable power can be generated from different sources like solar, wind, water, etc. in different communities and the same can be distributed through blockchain applications by establishing a microgrid system. Power can be transmitted between peer-to-peer consumers into the blockchain network.

However, one of the main challenges to implementing blockchain technology is power consumption. So, the use of the PoS consensus algorithm can be a better option instead of using the PoW algorithm to reduce the power consumption whereas the use of renewable energy for the PoW algorithm may be the alternative option.

V. DISCUSSION AND RECOMMENDATION

The background and architecture of the blockchain technology, the energy consumption, and the impact of blockchain, energy reducing methods by applying blockchain applications have been discussed in detail in this review paper. To overcome the enormous energy consumption issues for mining cryptocurrencies and reduce the carbon dioxide emission in the environment, the following important recommendations can be addressed in the future.

- To minimize the consumption of computing power, the Proof-of-Stake (PoS) consensus algorithm is highly recommended to use instead of use Proof-of-Work (PoW) algorithm for mining cryptocurrencies.
- Electricity consumption can be minimized by approximately more than 99% by using the PoS consensus algorithm which will lead to saving the computation power cost of the end-users.
- A significant amount of CO_2 emission in the environment can be minimized by using the PoS algorithm instead of using PoW algorithm.
- Renewable energy sources are preferable rather than non-renewable energy sources for mining cryptocurrencies by using the PoW algorithm, though it will not help to reduce the computational power, it will help to minimize the CO_2 emission in nature.

VI. CONCLUSION

Blockchain already has become one of the leading-edge technologies that provide the highest level of data security through using a cryptographic hashing algorithm where data tempering is almost impossible. Nowadays, the maximum application of this technology uses for mining cryptocurrency where bitcoin is the leader in the market. But the consumption of computing power is the major challenge to adopting this technology for mining cryptocurrency and other sectors. Due to the consumption of enormous energy, carbon dioxide emission becomes very high which ultimately pollutes the environment. An alternative solution like Proof-of-Stake consensus protocols has been proposed to use instead of the Proof-of-Work algorithm for mining cryptocurrencies. Not only that, but the use of renewable energy can also be an alternate option to use the Proof-of-Work algorithm for mining cryptocurrencies which is environment friendly. Blockchain technology might be more useful in different sectors if the high energy consumption is addressed properly which will be able to build a secure blockchain network and save the transactional cost as well.

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