Bitcoin and Its Energy Usage: Existing Approaches, Important Opinions, Current Trends, and Future Challenges

Usama Mir*
Saudi Electronic University, Senior Member IEEE
Dammam, Saudi Arabia
[u.mir@seu.edu.sa]
*Corresponding author: Usama Mir

Abstract

Recent years have shown a great interest of public in buying and selling of crypto/digital currency. With hundreds of digital currencies in financial market, bitcoin remains the most widely used, adapted, and accepted currency around the world. However, the critics of bitcoin still consider it a threat to modern day power usage. This paper discusses the important pitfalls, pros, and cons related to bitcoin's energy consumption. The paper begins by highlighting the flexibilities cryptocurrency can bring to online money transfers compared to traditional 'fiat' architecture. Then, the focus of the paper entirely remains on listing various facts related to bitcoin's energy utilization including a brief description of several emerging approaches for energy optimization. This paper is concluded by revealing key current challenges associated to bitcoin's energy usage.

.

1. Introduction

Recent years have shown tremendous growth in the usage of online exchange as a preferred way of money transfer. However, the current trends also depict that compared to traditional online money transfer provided by various banks and currency exchange organizations, more and more people are now shifting their focus towards crypto/digital currency due to its ease in usage, security, Pseudonymity in communication, and fast online transfers. Normally, these cryptocurrencies allow users to buy and sell tokens or coins having worth in real money such as (USD-United States Dollar), using various online platforms (e.g., Karken, Poloniex). Some of the most famous digital currencies are Bitcoin, Ripple, and Ethereum. Users can also trade between different currencies easily, for example, Poloniex allows its users to convert Bitcoin to Ripple just in one click within the span of a few seconds. Almost all cyprtocurrencies are deployed on the concept of famous 'Blockchain' [1], a technology facilitating and verifying the movement of digital money from one individual to another. This verification process (known as 'mining') is done with the help of Blockchain computers geographically placed in different locations. Blockchain is quite difficult to tamper by the hackers due to the strong correlation between blocks using unique hashes and its famous proof of work algorithm (explained later in forthcoming sections). Among several available digital currencies, Bitcoin (BTC) appears to be far more superior in terms of its worth, usage, and influence on market, therefore, the focus of rest of this article entirely remains on BTC.

Despite the above mentioned pros, BTC and other cryptocurrencies are facing the dilemma of consuming huge amount of energy to validate transactions. This energy usage can reach to an estimated value of around 213,101,865 kWh (kilowatt hour) a day (last updated in January 2020 in [2]), surpassing the power consumed by millions of houses in a large city. Initially, when Satoshi Nakamoto invented Bitcoin in the year 2008 as a decentralized network of digital money exchange, the number of BTC users and miners were few in number, thus, simple computer processors were enough to handle the BTC mining process. However, due to the current popularity of BTC and the spike it showed in 2017 reaching to a high price of up to 20,000 USD, BTC network has hugely grown in size and magnitude. In its core, BTC functions as a peer to peer (P2P) network of miners trying to solve a mathematical problem to validate a complete block of transactions. This mathematical puzzle gets harder to crack with increasing number of miners. Moreover, a group of miners solving the puzzle quickest gets the reward, however, this eagerness might in turn increase the overall energy consumption. Recently, BTC has gone through swear criticism over its energy usage being labeled as '*Bitcoin is killing the planet*' or '*BTC energy usage is huge - we can't afford to ignore it*' by the Guardian [3]. However, before reaching to any conclusion, it is very important to go through all the important details about BTC's working, examining in detail the factors contributing to BTC's high energy consumption, and highlighting any initiatives which may add up to bring green energy usage for BTC transactions. To the best of my knowledge, the current academic research lacks any of such work highlighting the aforementioned points, therefore, this paper is just an effort to fill up this research gap.

The rest of this article is organized as follows. In the next section, traditional fiat transactions are compared to BTC in a simple way. Then, all the current facts and figures related to BTC's energy usage are presented in Section 3. Though the research work is limited when it comes to proposing algorithms for BTC's green energy initiative, a few interesting efforts are still available and thus are highlighted in Section 4. Following that open issues and

future challenges related to BTC's energy consumption are discussed in Section 5. The conclusion is provided in the final section of this paper. Throughout this paper, I use similar words like 'crypto or digital' and 'energy, electricity, or power' interchangeably.

2. Traditional Money Exchange vs. Crypto/Digital Currency

Traditional banking systems deployed all over the world work on basic 'fiat' architecture. Typically, in each country, fiat money is maintained and controlled by the Governments where its value increases or decreases based on supply and demand and it is not backed by any physical money such as Gold or Diamond. All traditional currencies (ex. USD), fall under the window of fiat architecture. Normally, the users are required to open bank accounts by providing a lot of personal information and filling up quite a large number of forms. Physical presence and handwritten signatures are also mandatory. Banks provide numerous facilities to their customers including online money transfer, issuance of debit and credit cards, money exchange over the globe, ATM (automated teller machine) access, payment checks, and so on. Most of the times, an internet connection is not necessary when dealing with fiat money. A worldwide acceptance and convenience make fiat architectures more suitable for the majority of the people. Though, bank transactions in the form of online transfer or ATM/credit/debit card usage have the advantage of consuming minimal energy, we still cannot ignore the huge power used by geographically located bank branches (having high machinery) and the humongous manpower required to run bank operations, while making our energy calculations for fiat architectures.

Unlike above, the cryptocurrencies function differently from fiat money exchange where each coin or token maintains an online value against the real money (ex. 1 BTC coin equals 7500 USD). A user is required to register herself with any trusted dealer or website in order to buy or sell crypto coins. The registration process is normally quite simple and requires some personal information and ID to get started. The value of cryptocurrency is not defined and fixed by any banking or governmental authority. This value actually varies based on the interest, usage, and acceptance of people and merchants in digital market. Normally, a digital currency transaction passes through several nodes each trying to solve a mathematical problem. A transaction is accepted if the majority of the nodes validates it. Moreover, pseudonymity, seamless access to accounts, and less transactional fees are some of the advantages of digital currency. On the other hand, no physical infrastructure, lack of acceptance by most banks and governments, less trust by users, and the need of a mandatory internet connection to complete a transaction are some of the drawbacks associated with cryptocurrencies. In addition, a cryptocurrency transaction requires a huge amount of energy for each Blockchain transaction which is quite a concern. I elaborate further on this energy issue in my forthcoming sections.

Fig. 1 differentiates traditional and crypto money transfers, respectively. As per the scope of this paper, BTC is considered to be my chosen cryptocurrency. For simplicity, the figure shows a scenario of a customer who wants to pay for shopping at a supermarket. It is assumed that the customer does not have any cash amount to make this payment. Clearly, the traditional transaction (via credit card) has to pass through several steps before the amount is transferred to supermarket's registered bank account. This involves verification by the customer's bank and the credit card company, both charging buyer and seller with a fee for this transaction. The BTC transaction, on the other hand, looks quite simple and short. The customer uses her BTC wallet to pay which gets verified by the blockchain network. The payment is then made to supermarket's wallet with a fee. Despite having simplicity and pseudonymity of transactions,

the amount of energy taken by several distributed nodes of blockchain may sideline the pros provided by the BTC network. A brief summary of pros and cons of fiat and cryptocurrency architectures is provided in **Table 1(a)** and **Table 1(b)**.
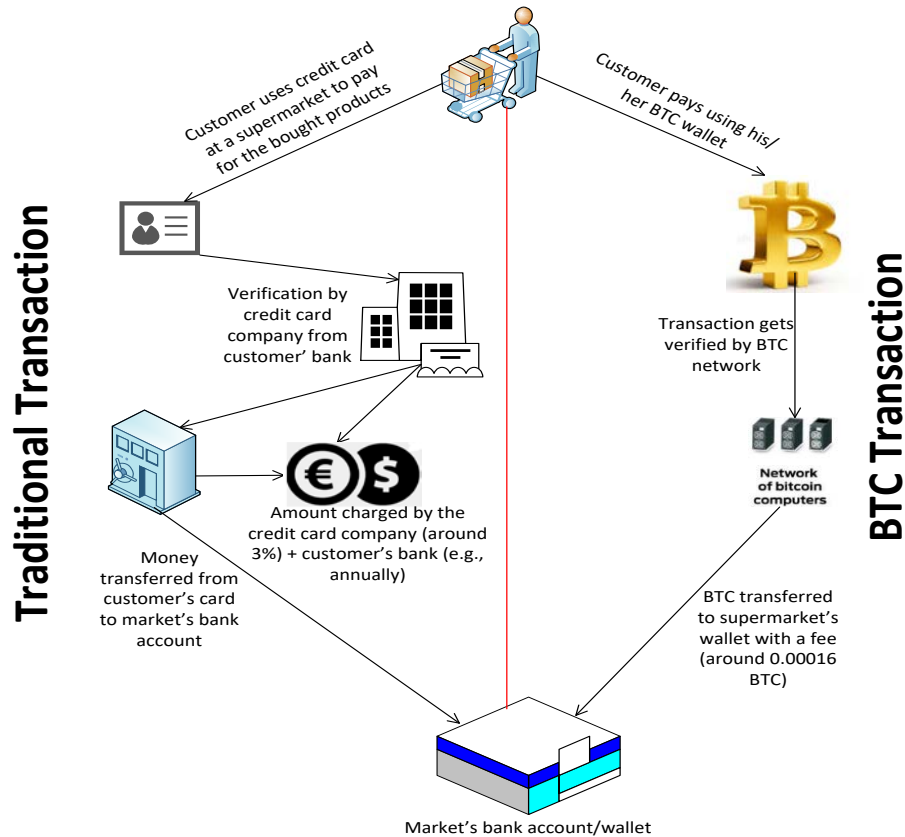

Fig. 1. Fiat exchange vs. BTC transfer

3. Energy Consumption by Bitcoin

Cryptocurrency analysts agree on one point: 'Bitcoin's energy consumption is huge.' Over the past few years, this energy usage has increased at an exponential pace. Some critics believe that BTC transactions consume more energy than a country's total usage. For example, the famous blog maintained by Digiconomist [2] rates BTC's energy usage to be approximately 0.3% of the total energy consumed by the world. Likewise, according to [4], the energy taken by a single BTC transaction equals the electricity required to serve almost nine homes in USA. In Venezuela, the huge burst in BTC transactions has led to complete *blackouts* in certain areas [4]. The author of [5] ranks BTC as 61st country in the world when it comes to energy consumption. Likewise, in a famous article published in May 2018 [6], the author adds up the network power usage by BTC hardware with the cooling and other electricity costs and estimates an approximate value of 2.55 gigawatts (GW). These calculations were made considering various mining machines such as the famous Antminer, AvalonMiner, and Bitfury. Following the current trend, the author estimates that the BTC's power usage may reach to an approximate value of around 7.7 GW in near future which is quite an alarming situation. Similarly, the authors of [7] build their analysis on the argument that the current

Table 1 (a). Traditional currency vs. Digital currency: Advantages

Traditional Currency (Fiat)	Crypto/Digital Currency
Strong control by banks and governments: Traditional currencies are controlled by various governmental and private banks all over the world. This gives an edge to the authorities to freeze someone's accounts in case of a fraud. Moreover, banks can easily manage interest rates, supply, reserves, interests, loans, and rates. In case of an emergency or a security breach, banks can easily trace people based on the huge amount of information and documents they have maintained for their customers.	**Complete Pseudonymity:** When we transfer coins/tokens from one wallet to another, the transaction does not carry any personal information of sender or receiver unless specified. Mostly, in BTC transactions, a wallet address is required with limited personal details. Thus, possibility of personal information leakage and identity theft remains quite low.
Variety in access: There are so many different options to use fiat currency such as online transfers, ATMs, credit/debit cards, checks, drafts, and so forth.	**Fast processing time**: Most cryptocurrency transfers are very fast (e.g., about two minutes for Ripple and 10 minutes for BTC). This makes digital currency more convenient especially when sending funds from one geographical region to another.
Worldwide acceptance: Since cyprtocurrencies are not widely acceptable, traditional money remains the primary source of usage allover the globe. This trend is expected to continue for decades especially in countries with poor Internet coverage.	**Distributed nature:** Almost all cryptocurrencies are deployed over distributed nodes which remain mostly active, thus reducing the possibility of service shutdown due to link failures.
Access without Internet: A person does not necessarily need an internet connection to use traditional currency. The money can be deposited or retrieved by personally visiting a bank's branch.	**Anytime access to your accounts:** Fiat accounts can be frozen or halted by the authorizes since they are regulated by the state banks. On the other hand, cryptocurrencies do not fall under the laws of any specific country or region, therefore it is pretty much rare to face any condition of frozen coins.
Infrastructural support: A lot of infrastructure is available to support banking transactions such as ATMs, bank branches, and credit bureaus. In addition, the acceptability of traditional currency is enormous ranging from a small payment at a street shop to an online payment for a real-state property. Money transfer agents such as Western Union and MoneyGram also facilitate the traditional money exchange.	**Low transactional cost:** The cost associated with digital currency transactions is very low. Normally, a BTC transaction costs 0.00016 BTC and a Ripple transfer costs 0.00001 XRP, respectively.
Energy efficient transactions: Most of the online, credit/debit card, and ATM transactions performed using fiat architectures are energy efficient.	**Easy and fast conversion:** Plenty of renowned platforms allow easy and fast conversion of one digital currency to another. For example, the famous website poloniex.com converts bitcoins to other currencies (ex. ripple, ethereum) within a few seconds.

hardware cost for mining process is too high and may result in lower revenues for miners if alternate green energy sources are not adapted in future. To validate their analysis, the authors use the famous quantile regression (QR) technique which mathematically determines the impact of BTC's energy usage on miners revenues. The empirical results clearly indicate that the BTC's current energy usage has a negative impact on miners revenues and thus, require miners to look for other cheap energy sources (such as coal) to sustain their profits. Likewise, in [8], the authors present a methodology to estimate bitcoin's energy consumption in terms of carbon footprint. The energy consumption is estimated based on the data provided by major hardware producers (such as Bitmain), the mining facilities (ranging from small to large scale), and the mining pools. These energy estimates are then converted to carbon footprints marginal and average emission factors for a geographical region. Results reveal that the carbon estimates for BTC are quite high and thus far from green. To be concise, **Table 2** summarizes

Table 1(b). Traditional currency vs. Digital currency: Disadvantages

Traditional Currency (Fiat)	Crypto/Digital Currency
Too much paper work: In order to maintain accounts, banks require too much paper work and personal information which may not be acceptable to certain customers. Due to the recent boom of IT, people prefer doing everything sitting at home on their handheld devices rather than visiting bank branches to open their accounts.	**Huge cost of energy:** Digital currency transactions take an ample amount of energy per transaction. This may range from 50 kWh to 950 kWh per transaction. We elaborate more on this issue in our forthcoming sections.
Less privacy: Since banks maintain too much information about their customers, therefore they continuously share personal data of customers with other authorities such as credit card bureaus resulting in privacy concerns.	**Limited acceptance:** Digital currencies are not widely acceptable for payments. Even BTC being the strongest cryptocurrency, its acceptance as a payment method (for buying and selling of stuff, bills, online shopping, etc.) is quite rare. Recently, we do hear some famous websites and corporations (such as expedia, Miscrosoft online store) accepting BTC as a payment method, however this access is only limited to some regions or countries.
High transactional cost: Banks and credit card transactions mostly have a high cost. Plus, the exchange rates and tax constraints may add up the cost for each banking transaction.	**Legal acceptance issues:** Many countries have restricted access to digital currencies. Recent harsh measures taken in China, Russia, India, and Pakistan are the examples of restrictions on BTC.
Vulnerability to economic situations: A country's economic situation affects the value of traditional currencies. In addition, global wars between big economies like China and USA may also result in price fluctuations.	**Non-reversible transactions:** Due to the decentralized nature of blockchain servers, it is almost impossible to reverse a transaction. This is quite contrary to the traditional banking transactions which are controlled by the centralized authorities and can be reversed in case of a mistake or an error.
Inefficiency in time: Normally, banking transactions (especially online fund transfers) take a lot of time resulting in days when sending money from one country to another. Moreover, banks in different countries work on distinct local systems, schedules, currencies, time zones, etc., making it more difficult to exchange money globally.	In addition to above, digital currency is also known to be the preferred method of money transfer for dishonest entities such as mafia, drug dealers, and illegal money launderers.

various important facts related to BTC's energy usage. Almost all the highlighted sources agree that one of the main factors for high energy usage of bitcoin lies within its mining process. In its core, BTC uses the famous proof of work (PoW) algorithm [1][9] where the authenticity of each BTC transaction is verified mathematically by the miners and the first miner confirming the legitimacy of a transaction gets the reward (as tokens or coins). Thus, the miner having high computational power succeeds and gets the reward. According to the Guardian [3], BTC's mining process is like a bidding competition where the players who bid fast might have a higher chance of winning the bid. Of course, in order to process transactions quickly and stay ahead in getting the mining reward, the miners need high processing machines which in turn consume loads of electricity. This process is repeated every ten minutes where one miner is guaranteed to get the reward. In other words, every ten minutes, one miner gets the reward for its energy consumption however, the power used by all other miners is wasted since they get nothing out of the mining process.

Table 2. BTC's energy consumption summarized from various well-known sources

Ref.	BTC Annual estimated electricity consumption (TWh or kWh)	BTC energy consumption normalized to world energy consumption (in %)	Energy consumed per BTC transaction (kWh)	Other relevant facts
[2]	77.78 TWh Dated: March 2020	0.3%	950	- BTC utilizes almost equal amount of energy consumed by the whole Switzerland. - In Czech Republic, BTC consumes 60% of country's total electricity. - According to a rough estimate, BTC uses four times more energy than 100,000 VISA/MASTER card transactions.
[3]	42000000000 kWh Dated: January 2018	0.2%	Not specified	- BTC utilizes almost equal amount of energy consumed by New Zealand and Hungary. - The only way BTC's energy consumption goes down is due to the decline in its market value.
[4]	31000000000 kWh Dated: December 2017	Not specified	Same as [2]	- The computing power of BTC network is 100,000 times larger than 500 supercomputers. - Most BTC miners are from China who use water dams as a cheapest way for energy generation.
[5]	21,776 TWh Dated: Late 2018	0.13%	Same as [2]	- If we refer to all BTC miners as one country, then this country would be at 61st place in the world in terms of energy consumption. - If BTC's energy consumption continues to rise at the same pace as now, then it will consume almost all the world's electricity in coming years. - China tops the list of countries with least BTC energy consumption relative to country's total usage. Saudi Arabia stands at 13th place in the list.
[12]	Same as [2]	Not specified	Same as [2]	- In most countries such as China and Iceland, miners have started looking for cheaper and green energy sources for BTC transactions.

Some of the above blogs also (factually) compared BTC's energy consumption with traditional visa transactions and fiat currencies. According to [10], one BTC transaction equals to the cost of 100,000 visa transactions. Moreover, the authors of [11] combine the hashrate (the process of finding the next block and getting the reward for the miner) with the efficiencyof using different hardware (ex. 0.126 Megahash/J for core i7 950 processor), to calculate the total energy consumed by BTC network for mining. This energy equals 10^{10} J/sec, which is more than the energy demands of Ireland. However, the aforementioned calculations do not include the electricity used by several offices deployed by visa all over the world with workforce for distribution and physical transfers of amounts from one area to another including fuel costs. In addition, important factors such as security, card printing, code generation on mobile devices, and investigation of fraudulent payments and cards have also been ignored in [4][11].

Despite criticism on BTC's energy usage, some digital currency experts are optimistic about BTC's importance and its long-lasting future. The main motivation for this optimism lies with the convenience BTC users have when it comes to transferring money and coins from one account to another without any effort. These users are not comfortable with the hurdles placed by the traditional banks requiring a lot of steps for verification, validation, and personal information to open accounts and transfer money. Moreover, with its current value of around 7500 USD per coin, BTC provides the flexibility in transferring coins worth of up to several thousand USD (almost 25000 USD on average in a day) with a few clicks, in no time. Thus, the optimists believe that the benefits of BTC cannot just be ignored for the sake of its energy constraint. According to the New York Times [12], instead of exaggerating on BTC's power usage, one should realize its benefits as a universal digital currency and look for cheaper and green energy sources such as hydropower and solar for BTC transactions. The famous blog maintained by BitStarz news [13] criticizes the BTC energy related facts presented in [2] calling them unrealistic. The authors of [13] believe that '*BTC is greener than you think*' when they compare it with fiat money transfers where a transaction passes through so many data centers for verification and fraud detection before the user actually gets the money, thus making fiat transactions as power hungry as BTC [14]. Likewise, a recent GLOBAL CRYPTOASSET BENCHMARKING STUDY [15] points out that the share of using renewable energy sources in mining is around 28%, however, this percentage might vary from one facility to another. The renewable energy (such as hydroelectric power) usage remains higher in facilities (ex. Western China, North East USA) where the demand is considerably lower than the supply and the unit price is cheap as well. Thus, incentives such as cheap unit prices with excessive availability of renewable resources may result in increasing the aforementioned percentage. On the other hand, some miners may also remain hesitant to adapt green energy sources due to high prices. For example, a recent article in 'cointelegraph' explains the situation in Quebec region of Canada where big crypto giants such as Hamel did not participate in the renewable energy sources bidding process due to a high price set by the local authorities [16].

4. Approaches for Energy Optimization of BTC Transactions and Mining

Bitcoin related energy issues have been discussed in several blogs, forums, and websites. These blogs normally contain an introduction to BTC with a small discussion on the energy perspective. When it comes to traditional R&D with the focus on designing energy efficient algorithms for BTC transactions, various research efforts are available, however considering the scope of this paper, I summarize some important ones in this section. The important points

related the aforementioned approaches are also highlighted in **Table 3**.

4.1 Proof of Authentication (PoAh) [17]

In [17], a lightweight (energy efficient) algorithm named as proof of authentication (PoAh) for IoT blockchains is introduced. Since the devices in an IoT blockchain are restricted with minimal battery resources, therefore, traditional PoW and PoS algorithms cannot be applied directly.

Table 3. Attributes of existing energy efficient solutions proposed for BTC

Ref.	Type of Document	Algorithmic approach	Main design consideration/ parameter	Hardware consideration	Type of reward for Miners
PoAh [17]	Research paper	Proof of authentication	Hashrate	Yes	Reward from blockchain only to active peers
BE [18]	Research paper	Smart contract	No central entity	Yes	Gain in electricity/energy
EASC [19]	Research paper	Smart contract	No central entity	Yes	Gain in electricity/energy
BTC-G [9]	Whitepaper	Proof of Stake	Hashrate	Yes	BTC transaction fee from users + Reward from the blockchain
BTC-C [20]	Whitepaper	Proof of Green	Voting/trust	Yes	Not specified but most probably energy gain
Intel's PoE [21]	Whitepaper	Proof of Elapsed	Hardware (Chipset)	Yes	Not specified since the algorithm is complimented by the Intel's improved hardware (chipset) designed for BTC transactions

Normally, in PoW and PoS, users can go online just to create blocks and then they remain offline, as a result, the nodes may get rewards for staying offline. PoAh addresses the aforementioned limitation by rewarding only those peers who stay active during the mining process. Moreover, PoAh increases the security of nodes since the reward goes to active (online) members and holding the currency for longer periods (just by staying offline) does not provide any incentive to miners. Later, the algorithm has been implemented in both via simulation and real-time experiments showing that the PoAh algorithm achieves less latency than traditional PoW algorithm.

4.2 Bit Energy (BE) [18]

The authors of [18] propose a new BTC transaction system allowing market users to buy and sell bitcoins without involving any centralized entity or server. However, in essence, the traditional blockchain model for validating BTC transactions has been used. Another important feature of BE is the development of a smart computerized protocol which puts every

BTC transaction under some agreement or contract. The authors claim the effectiveness and scalability of their BE model through real-life case studies, however no concrete evidence has been given. The work presented in [19] also proposes a smart protocol for energy optimization however, this work has the same limitations as those mentioned for [18]. For the sake of this paper, the approach in [19] has been named as **Energy Auctions based on Smart Contracts (EASC)**.

4.3 Bitcoin Green (BTC-G) [9]

In addition to above, recent research comprises of a few interesting whitepapers addressing the energy efficiency concerns for BTC networks. The most interesting work has been done by the Bitcoin Green Team to offer a decentralized BTC buying and selling system with the primary focus on energy efficiency [9]. One prominent feature of [9] is to use 'proof of stake (PoS)' algorithm instead of traditional PoW algorithm. Unlike PoW, PoS rewards miners on the basis of the wealth (or coins) they pursue. Therefore, any user having a simple desktop computer can be rewarded since no extra computational capabilities needed to participate in BTC mining. This significantly reduces the energy consumed by the hardware resources. Moreover, to avoid the effects of unjustified rewarding, a new 'Green Protocol' has been introduced which awards miners with a fixed amount of coins or tokens (ex. 10 coins in a day). This reward is calculated irrespective of the number of coins a miner has in her wallet.

4.4 Bitcoin Clean (BTC-C) [20]

Another very interesting concept is proposed in a whitepaper [20] where the authors develop an algorithm known as 'proof of green (PoG).' The basic concept of the proposed work is to tilt the focus of miners to green energy sources (ex. solar) for BTC transactions. For this, the miners submit their proofs of using green energy sources (such as any bill from a solar energy provider) to be eligible for BTC mining. A ranking system is developed which allows experienced miners to recommend or reject new miners. A miner qualifies for the mining if she has a rank of more than hundred (100). Moreover, the miners also have an 'impact' on other miners votes and proposals. For example, a miner having an impact of five (5) is treated as an experienced and well-reputed one, while this impact value remains low for other inexperienced and less reputed miners. The creators of PoG are confident that their approach will surely make an impact on BTC energy savings; however, in near future, this objective seems far from achievable.

4.5 Intel's Proof-of-Elapsed (PoE) [21]

A promising new algorithm supporting the green energy initiative for blockchain transactions has recently been proposed at the Intel [21]. This algorithm known as PoE, relies on 'Hyperledger Sawtooth' blockchain software that Intel is planning to incorporate with its future processors. This software allows each miner to go to sleep or idle mode for a random period of time. The software then rewards the miner who awakes the first and bids for mining. Thus, compared to PoW, in PoE, at each instant of time, only one miner participates in the mining process which seriously saves the overall energy. However, the cost of such hardware with built-in software might be higher. Moreover, the PoE algorithm may result in selecting the miner with lowest bid since there is no competition at the bidding process.

    Above discussion is a mixture of articles from both academia and industry. References [18][19] rely on the smart contract protocol, [9] uses PoS, [17] proposes PoAh, [20] relies on PoG, and [21] is based on Intel's PoE algorithms, respectively. In most of the approaches,

hashrate is considered to be the main design, voting, and decision making parameter. Each algorithm is designed by considering the minimal power constraint of hardware. In all approaches, miners are rewarded with more coins plus the transaction fee, however, the algorithms in [18] and [19] also provide miners with a gain in their energy/power resources for the successful completion of a transaction.

5. Current Trends and Future Challenges

Recently, Bitcoin is at a crucial stage where its price roams around 6000 USD mark. Other famous currencies such as Ripple, Etheruem, Litecoin, BitcoinCash, etc., are also affected by the current low market trends. The investors are hesitant to put up more money unless they are sure about the viability of their investments in digital currency. Some harsh measures taken by the governments of China, Russia, and India have also played a role in the recent price uncertainty. On the other hand, a few optimists still believe that BTC is there to stay and it will rise against all the odds. Quite recently, some crypto based platforms suffered from security and hacking issues, however, this discussion is not within the scope of my work. Thus, this section entirely focuses on trends and issues related to bitcoin's energy usage. In order to get details on other important bitcoin related concerns (especially security), interested readers may refer to a promising work presented in [22].

5.1 Need for Alternate Energy Sources

As specified throughout the paper, the main concern for BTC lies with the energy sources. In most countries, people are not looking for any alternates (such as solar and hydropower) to validate BTC transactions due to lack of motivation, less resources, and limited infrastructural support. In small counties like Hungry, where BTC transactions could take half of country's total power, people should certainly introduce new and green ways to save the energy lost in BTC transactions. The government of these countries should also promote the green energy initiative, provide support to miners, and ask big crypto investors to put their money in developing green energy infrastructure. The measures taken by miners in China can be considered as a milestone. Despite government's pressure on banning BTC and introducing new cryptocurrency in conjunction with Russian government, some of the Chinese miners are still looking to deploy solar, wind, and dam based energy sources for BTC transactions. Energy generation through dams can also be an option for other countries like USA where from an overwhelming number of 80 to 90 thousand available dams only a fraction is used for the production of electricity.

5.2 Algorithmic Change

As highlighted above (in Sections 3 and 4), the PoW algorithm used by BTC has its limitation. It is designed in a way that more energy is wasted on unnecessary computation. Other algorithms such as PoG and PoS are there to support the green energy initiative and some famous cryptocurrencies (such as Etheruem [23], Dash, Neo, Reddcoin) have also started using PoS, but more efforts are still needed to apply such techniques for BTC transactions.

5.3 Handling the Hardware Constraint

Another vital concern is related to the hardware used for BTC transactions. In order to be rewarded, the BTC miners try to use more advanced computer hardware having high processing power and speed, which in turn increases the hardware cost and consumption of

energy. According to the sources sighted in [13], back in 2008 when BTC was first launched, if it had the same number of transactions and miners as it has right now, then it would have consumed an equal amount of energy as of our whole planet. The only reason we are not in this situation is because of the continuous upgrade in computer hardware and processing capabilities these days. Moreover, BTC transactions may also affect the electricity infrastructure deployed in many underdeveloped countries where people use power illegally. The recent blackout happened in Venezuela due to illegal electricity usage of miners is an example of the damages BTC transactions can cause to any deployed electricity infrastructure [4][13].

5.4 Creating Awareness and Trust

BTC users from prosperous countries are already aware of its huge energy consumption, however some awareness needs to be created among the miners of under developing countries where BTC has started to be a preferred method for money exchange. To add up the flavor, famous BTC exchange platforms (such as poloniex, kraken and many others) should contribute to the energy saving initiative, for example, by putting up 'green energy usage logos' on their websites. The governments of under developing countries should also realize the pros of BTC and play a part in encouraging and supporting miners to look for alternate energy sources. As specified in [21], platforms can be developed to combine both the benefits of traditional and digital currency systems where famous banks could contribute in sharing the energy load while their customers might enjoy the luxury of having online wallets, secure and decentralized transactions, and transparency provided by the blockchain network.

5.5 Scalability Issue

Scalability is another common and important issue related to blockchain technology. As specified in [24], three factors may affect the scalability of digital currencies. First, the *throughput* since the current blockchain transactions are limited to a small number (seven transactions per second). Then, the *storage* because a lot of data is generated by each miner node surpassing the capacity of a simple computer, and finally the *networking* since a lot network traffic is generated due to broadcasting method adapted by blockchain technology. Therefore, approaches such as the one presented in [25] must be developed by keeping the scalability concerns into consideration.

5.6 Growing Electronic Waste (e-waste)

As highlighted in [26], one of the important issues with BTC is the growing amount of electronic waste (e-waste). According to the statistics presented in [26], miners replace their specialized hardware approximately after every 1.5 years to be able to compete with other miners. This results in obsoleting the old hardware and thus, creating a huge amount of wastage (almost 11.5 kilotonnes per year dated January 2020). Therefore, certain policies must be designed and initiatives must be taken to overcome this wastage issue. One of the solutions mentioned in [26] and also highlighted throughout this paper is to totally replace BTC's mining process with algorithms such as PoS, PoG and so on.

5.7 Less Academic Research in the Area

To sum up this section, I would like to highlight the concern of having less academic research related to BTC's energy concern. Though, a number of algorithms is available in literature such as PoS, PoG, PoAh, BE, BTC-G, PoW and PoS hybrids, proof of USEFUL, proof of BID,

and proof of burn, still more articles are needed when it comes to pure academic research.

6. Conclusion

This paper investigates issues related to bitcoin's energy usage including the limitation of its current proof of work algorithm and the approaches suggesting alternative optimized solutions. The paper also reveals the opinions of several digital currency experts stating that the current energy usage of bitcoin is quite a lot (equaling it to the power consumed by most small countries in the world), which needs to be changed. However, the huge flexibility bitcoin offers in money exchange in terms of time saving, secure transactions, and universal acceptance cannot be ignored either. In addition, the last section of this paper also highlights important current and future problems which should be addressed in order to promote green energy initiative for bitcoin transactions.

References

[1] J. Yun, et al., "MMOG User Participation Based Decentralized Consensus Scheme and Proof of Participation Analysis on the Bryllite Blockchain System," *KSII Transactions on Internet and Information Systems*, vol. 13, pp. 4093-4107, 2019. Article (CrossRef Link)

[2] https://digiconomist.net/bitcoin-energy-consumption

[3] https://www.theguardian.com/technology/2018/jan/17/bitcoin-electricity-usage-huge-climate-cryptocurrency

[4] https://grist.org/article/bitcoin-could-cost-us-our-clean-energy-future/

[5] https://powercompare.co.uk/bitcoin/

[6] A. De Vries, "Bitcoin's growing energy problem," *Joule*, Vol. 2, pp. 801-805, 2018. Article (CrossRef Link)

[7] D. Das., et al., "Bitcoin's energy consumption: Is it the Achilles heel to miner's revenue?," *Elsevier Economics Letters*, Vol. 186, 2020. Article (CrossRef Link)

[8] C. Stoll, L. Klaaßen, and U. Gallersdörfer, ''The carbon footprint of bitcoin," *Joule*, vol. 3, no. 7, pp. 1647–1661, 2019. Article (CrossRef Link)

[9] The Bitcoin Green Team, "Bitcoin Green: The Sustainable, Proof-of-Stake Bitcoin," *Whitepaper*, December 2017. https://savebitcoin.io

[10] https://www.abc.net.au/triplej/programs/hack/bitcoin-mining-consumes-quarter-of-australia electricity/9792962

[11] K. J. O'Dwyer, and D. Malone, "Bitcoin Mining and its Energy Footprint," in *Proc. of 25th IET Irish Signals & Systems Conference 2014 and 2014 China-Ireland International Conference on Information and Communications Technologies, ISSC'14/CIICT'14), Limerick, Ireland*, 2014. Article (CrossRef Link)

[12] https://www.nytimes.com/2018/01/21/technology/bitcoin-mining-energy-consumption.html

[13] https://www.bitstarz.com/blog/debunking-the-great-bitcoin energy-consumption-myth

[14] P. Fairley, "Ethereum will cut back its absurd energy use," *IEEE Spectrum*, vol. 56, pp.29-32, 2019. Article (CrossRef Link)

[15] M. Rauchs, et al., "2nd global cryptoasset benchmarking study," *SSRN*, p. 96, 2019. Article (CrossRef Link)

[16] https://cointelegraph.com/news/has-quebec-missed-the-ship-for-attracting-cryptocurrency-miners

[17] D. Puthal, et al., "Proof-of-Authentication for Scalable Blockchain in Resource-Constrained Distributed Systems," in *Proc. of 37th IEEE International Conference on Consumer Electronics (ICCE)*, 2019. Article (CrossRef Link)

[18] J. Luo, et al., "Bit-energy: An innovative bitcoin-style distributed transactional model for a competitive electricity market," *IEEE Power & Energy Society General Meeting, Chicago, USA*, 2017. Article (CrossRef Link)

[19] A. Hahn, et al., "Smart contract-based campus demonstration of decentralized transactive energy auctions," in *Proc. of IEEE Power & Energy Society Innovative Smart Grid Technologies Conference, ISGT'17, Washington, USA*, 2017. Article (CrossRef Link)

[20] bitcoinClean, "bitcoinClean: A Bitcoin hard fork with 8MB blocksize and replay protection that ensures renewable energy use for mining," 2018. https://Bitcoinclean.org

[21] P. Fairley, "Blockchain world - feeding the blockchain beast if bitcoin ever does go mainstream, the electricity needed to sustain it will be enormous," *IEEE Spectrum*, vol. 54, no. 10, pp. 36–59, 2017. Article (CrossRef Link)

[22] M. Conti, et al., "A survey on security and privacy issues of bitcoin," *IEEE Communications Surveys & Tutorials*, vol. 20, pp. 3416-3452, 2018. Article (CrossRef Link)

[23] D. R. Lee, et al., "Poster: A Proof-of-Stake (PoS) Blockchain Protocol using Fair and Dynamic Sharding Management," in *Proc. of ACM SIGSAC Conference on Computer and Communications Security (CCS), London*, pp. 2253-2555, 2019. Article (CrossRef Link)

[24] J. Xie, et al., "A Survey on the Scalability of Blockchain Systems," *IEEE Network*, vol. 33, pp. 166-173, 2019. Article (CrossRef Link)

[25] S. Biswas, et al., "A Scalable Blockchain Framework for Secure Transactions in IoT," *IEEE Internet of Things Journal*, vol. 6, pp. 4650-4659, 2019. Article (CrossRef Link)

[26] https://digiconomist.net/bitcoin-electronic-waste-monitor/

Usama Mir received the B.S. degree (Hons.) in computer engineering from the Balochistan University of IT, Engineering and Management Sciences, Pakistan, in 2006, and the master's and Ph.D. degrees in computer science from the Troyes University of Technology, France, in 2008 and 2011, respectively. He was a Post-Doctoral Fellow with Telecom Bretagne, France, from 2011 to 2012. He was the Head of the Electronics Engineering Department, Iqra University Islamabad, Pakistan, from 2012 to 2015. He is currently an Assistant Professor with Saudi Electronic University, Saudi Arabia. His research interests include big data analysis, resource allocation and handoff management in cognitive radio systems, bitcoin and digital currencies, wireless communications and networking, and multi-agent systems.