The Influence of Blockchain Technology Stakeholders on the Environment

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Blockchain technology emerged in the past decade and became popular ever since the implementation of Bitcoin, one of the most popular blockchain technologies. In 2009, Bitcoin was incepted by an anonymous group of developer(s) going by the name of Satoshi Nakamoto. Since then, Bitcoin has served around 62.5 million transactions between 109 million accounts (Böhme et al., 2015). In recent years, other applications of blockchain technology have been on the rise, like biomedical devices for example. The usage of block technology allows for decentralized management, so biomedical and health care stakeholders can collaborate with one another without giving up control to a central management system (Kuo et al., 2017). Another field that blockchain technology applies to is the energy sector, as it allows for the potential to improve the efficiency of current energy practices and processes (Andoni et al., 2019). These are just a couple of examples out of many different cases of how blockchain technology can be applied to different fields. Blockchain technology can be applied to fields that one would not imagine conventionally. However, despite the variety of applications that blockchain technology enables, the energy consumption associated with blockchain technology is excessive and in turn impacts the environment.

Blockchain uses a Proof-of-Work (PoW) consensus mechanism to verify and validate transactions, which involves many energy-intensive computations being done simultaneously (Shi et al., 2023). As of July 2021, two blockchain networks combined, Bitcoin and Ethereum respectively, consumed 190.13 TWh of energy, which is more than Thailand with only 185.85 TWh consumed (Kohli et al., 2022). This is detrimental to the environment, since having high energy consumption leads to high carbon footprint (Kohli et al., 2022). With the increase in energy usage and carbon footprint, Bitcoin could push global warming above 2 °C by the year 2100 (Masanet et al., 2019).

In this paper, I argue that the negative environmental impact caused by blockchain technology is the product of multiple stakeholders that contribute to the use of this technological artifact. To support my argument, I will be applying the Actor-Network Theory framework to explore how the interaction, contributions, and motivations between networks of stakeholders of blockchain technology influence the extensive usage of such technology and thereby influence the negative impact on the environment.

Literature Review

My research will be covering topics that explain the mechanisms that influence the high energy consumption by blockchain technology, the motives, and reasons why Bitcoin miners contribute to mining blockchain technology such as cryptocurrency, and finally the motives and reasons why blockchain core developers contribute to blockchain technology.

One group of sources that I have gathered pertains to discussing the prominent blockchain mechanisms that are significant contributors to high energy consumption. The central claim of these sources is that mainstream blockchain technology mechanisms consume a lot of energy, which in turn produces carbon emissions that cause environmental problems such as climate change. In particular, the Proof-of-Work (PoW) mechanism was the first consensus mechanism proposed for blockchain networks and so it is the most prominent (Nakamoto, n.d.). PoW mining has high computational needs which creates limitations to the continuous use of blockchain technologies that utilize this mechanism (Mishra, n.d.). Mining processes that use PoW are predicted to generate 130 $MtCO_2$ by the year 2024 (Jiang et al., 2021). According to Kohli et al.

(2022), the PoW mining process involves creating a new block with a hash that is computed by using the previous 256-bit hash of the previous block, the Nonce and Merkle root. The paper indicates that it is exceedingly difficult to compute the nonce, which provides proof of the amount of computational power put in by the miner. Mining becomes harder over time, so PoW ends up becoming an arms race of computational power and resources because miners with more powerful devices can compute more hashes per second (Kohli et al., 2022). These sources show that the blockchain itself and the mechanism it uses are core contributors to the high energy usage. As a result of such energy-intensive tasks, it generates grand amounts of carbon emissions. Therefore, the blockchain technology itself is one of the stakeholders that contribute to the negative impact on the environment.

Another group of sources I collected provided insight on the motivations of Bitcoin miners for engaging in mining practices within blockchain technology. Khairuddin & Sas (2019) say that there are three sources of motivation for miners: earning potential through fee-based rewards, experimenting with Bitcoin blockchain technology, and lack of regulation regarding taxation of miners' fees. Miners are compensated by solving a difficult puzzle with a fixed sum of bitcoins by the protocol, which is the block reward (Dimitri, 2017). As the source suggests, profitability is a big motivation for Bitcoin miners. In addition, miners gain an initial interest out of pure curiosity (Khairuddin & Sas, 2019). This goes hand in hand with the idea of wanting to learn about the Bitcoin currency, which is achieved by leveraging social networks of Bitcoin users (Sas & Khairuddin, 2017). Lastly, although there is enormous potential to generate income from mining Bitcoin, the taxation of such income is still not regulated – the discretion to pay tax remains in the hands of the miners (Khairuddin & Sas, 2019). Miners have overarching motivations that influence them to contribute to blockchain technology, namely economic incentives, and learning. While keeping in mind the highly intensive consumption of blockchain technology mechanisms, and because miners are a major user demographic of blockchain technology in terms of continuous use, they are crucial to the contribution to the environmental impact of blockchain technology.

Lastly, another group of sources centered around explaining the motivations of blockchain core developers. They argue that the primary motivations of blockchain core developers are ideology, external rewards, intrinsic factors, technical attraction, learning and community recognition (Bosu et al., 2019). Also, with blockchain development being open-source, both blockchain development and general open-source software projects are strongly associated in that developers in both have learning as a primary motivation (Yunwen Ye & Kishida, 2003). Furthermore, Yunwen Ye & Kishida (2003) say that learning is a driving force that motivates developers to get involved in open-source software projects because it provides intrinsic satisfaction. As mentioned earlier, blockchain core developers also exhibit intrinsic satisfaction and it is one of their primary motivators. Interestingly, blockchain core developers share a primary motivation with Bitcoin miners because both groups gain external rewards. In the case of blockchain core developers, they earn money by working on blockchain software projects as well as by holding cryptocurrency and thus are motivated to increase its value (Bosu et al., 2019). Learning is also another primary motivation shared with Bitcoin miners. Overall, blockchain core developers share a lot of the same motivations as Bitcoin miners, but the difference is that developers are the ones who develop the software for users. Nonetheless, they are core contributors to the environmental impact caused by blockchain technology because they are the ones who develop and maintain such technology.

Methodology

To investigate the environmental impact of blockchain technology, I will be specifically looking at secondary data on Bitcoin's high energy usage, interviews on Bitcoin miners and finally interviews on blockchain core developers. When looking at the scale of the environmental impact by blockchain technology, and especially looking at which types of blockchain technologies contribute the most, Bitcoin can be considered an exemplary case since cryptocurrencies are an important application of blockchain technology and Bitcoin is the most valuable and widely used cryptocurrency (Islam et al., 2019).

The secondary data on Bitcoin's high energy usage entails information about the projected energy consumption by Bitcoin, carbon emissions because of the energy usage, and the nature of the mechanism that Bitcoin uses that yields the high energy consumption. Jiang et al. (2021) uses a theory of carbon footprint to create a theoretical model for Bitcoin Blockchain carbon emission assessment and policy evaluation. The paper establishes the boundary and feedback loops for the Bitcoin blockchain carbon emission system, which is used as the theoretical framework to explore the carbon emission mechanism of Bitcoin. The Bitcoin blockchain carbon emission model (BBCE) model collects carbon footprint of Bitcoin miners in both coal-based and hydro-based energy regions to calculate the overall carbon emission flows (Jiang et al., 2021). In addition, Kohli et al. (2022) goes into the detail of the mechanism that Bitcoin operates on, namely the Proof-of-Work (PoW) mechanism. Such data is relevant to my research because it elaborates on the specific technological contributions that Bitcoin has on the negative impact on the environment.

The interviews on Bitcoin miners and blockchain core developers expand on the motivations behind miners' extended use of Bitcoin and the reasons for developers working on blockchain technology. Regarding a study conducted on Bitcoin miners, 20 participants with varying mining expertise and professions were recruited (Khairuddin & Sas, 2019). In this study, interviews were semi-conducted between November 2015 and February 2016. The aim of this study was to explore the mining process from the miners' perspective as well as learn about their motivations and approaches to mining. In another study interviewing Bitcoin users (Sas & Khairuddin, 2017), some questions asked were: "Why are you interested in bitcoin?", "How did you learn about bitcoin?", and "Which are the benefits and challenges of using bitcoins?". The goal of this study was to explore the motivation of Bitcoin users in general as opposed to only Bitcoin miners. These studies are significant to my research in that they provide insight on why these groups of blockchain stakeholders contribute to blockchain technology. This helps to establish them as factors that play a role in the environmental impact of blockchain technology – without such contributions, blockchain technology on its own would not be able to exert an influence on the environment.

I will be using Actor-Network Theory (ANT) to analyze the data from the sources I have gathered and to explore the environmental impact of blockchain technology. For some background, ANT explores how networks are built or assembled by actors to reach a certain objective (Latour, 2007). This book explains that ANT provides a sociotechnical lens to analyze the interactions between technology and human processes. An actor in ANT is defined as any element that can make other elements dependent upon itself and can include both social and technical entities (Islam et al., 2019). Latour (1990) also says that any actor is equal in creating a network. Therefore, I will apply ANT to my research to understand the process behind the environmental impact made by blockchain technology. I will be explaining the environmental impact as a translation process of ANT, which is one that creates a temporary movement from one order to another due to changes in the alignment of interests within a network (Sarker et al., 2006). There are four phases in the translation process: problematization, interessement, enrollment, and mobilization (Callon, 1984). Callon (1984) explains problematization as the process in which the focal actor (the key actor) defines the problem, identifies relevant actors, and explains how the problem affects those actors. The paper continues to explain that interessement involves convincing other actors to have an interest aligned with the focal actor. Followed by interessement is enrollment, in which a newly formed network has newly defined roles for each actor (Callon, 1984). Finally, mobilization occurs when actors within the network gain active support.

Defining the Actors of the Network

I will first identify the three distinct types of focal actors of Bitcoin: the blockchain, miners and core developers. These actors will be classified into three dissimilar categories to show the diversity in the nature of the actors: social, technological, and economic. Table 1 is adapted from (Islam et al., 2019) and shows few of the main actor types and their actor-networks.

The first actor displayed in Table 1 is blockchain. According to Islam et al. (2019), blockchain consists of algorithms that set rules for the operation of itself. It calls for other actors such as rules, ideologies, algorithms, internet, computing power, storage space, and incentives. Specifically for Bitcoin, these set of rules include the core ideas of decentralization, democracy, and anonymity. Technologically, these core ideas are implemented using algorithms that are operated over a system of computers. Finally, from an economic perspective, blockchain provides a mechanism that determines the economic incentives for miners.

The second actor represented in the table are miners. Miners consist of individual people with limited computing power and larger groups of people with greater computing power (Islam et al., 2019). Within the actor-network of miners can include other technological actors such as computers, coding hardware, electricity, and web applications to mine and receive economic rewards.

The third actor listed are core developers. In terms of Bitcoin, core developers are responsible for developing the Bitcoin source code (Islam et al., 2019). Like miners, the technological actor-networks that are associated with core developers are computers and software applications. They need such technology to learn about coding blockchain technology. Economically, core developers receive employment opportunities from companies that work with blockchain technologies and gain insight on obtaining assets.

Table 1: Table depicting actor diversity

Actor	Social	Technological	Economic
Blockchain	Set of rules, ideologies	Algorithms, internet, computing power, storage space	Incentives, price of electricity
Miners	Individual miners, mining pools, mining interactions within community	Computers, computer applications, electricity, web-based applications	Source of profit
Core developers	Individual developers, groups/networks of developers	Computers, software applications	Employment, asset ownership

Environmental Impact as a Translation Process

Problematization in actor-network theory refers to an instance in the translation process in which a focal actor establishes the identities and interests of other actors that are aligned with its own interest (Callon, 1984). In the study that Bosu et al. (2019) conducted, the primary motivations of blockchain core developers are ideology, external rewards, intrinsic factors, technical attraction, learning, and community recognition. Ideology was the most popular reason that blockchain core developers contribute to blockchain technology with 36.9% of respondents of the study stating ideology as their main motivation. In particular, the primary motivation behind Bitcoin for blockchain core developers was that it was the first blockchain based cryptocurrency that created a decentralized currency that cannot be manipulated by any type of central authority (Bosu et al., 2019). In the same study, external rewards (36.2% of respondents) were the second highest motivation for blockchain core developers. After all, their contribution to blockchain technology projects helps them earn money and as holders of cryptocurrency, they are naturally motivated to increase the value of cryptocurrency. Furthermore, 26.9% of respondents considered blockchain a promising technology for the future want to learn.

On the other hand, the primary motivations of Bitcoin miners are earning potential through fee-based rewards, experimenting, and learning about Bitcoin blockchain technology, and lack of regulation regarding taxation of miners' fees (Khairuddin & Sas, 2019). There are also some important design features related to mining that are valued by miners. For instance, the decentralized and transparent mining protocol is valued by more than a quarter of participants of a study exploring the motivations and challenges of Bitcoin miners (Khairuddin & Sas, 2019). Khairuddin & Sas (2019) say that the mining protocol can be attributed to the proof-of-work mechanism, which reflects miners' systematic and transparent competition for finding the quickest and longest solution to a block. As a reminder, the proof-of-work mechanism involves many high-energy calculations being executed at the same time (Shi et al., 2023) and was the first consensus mechanism proposed for blockchain networks and so it is the most prominent among most blockchain networks (Nakamoto, n.d.). In terms of learning about Bitcoin blockchain technology, miners leveraged the emerging social network of bitcoin users, but started with self-guided online research (Sas & Khairuddin, 2017). The biggest motivator for miners is the potential to earn a lot of fee-based rewards because of feasibility to generate profit (Khairuddin & Sas, 2019).

In explaining the environmental impact of the high energy usage of blockchain technology, I will establish that blockchain core developers were the focal actors. This is because they are the ones who developed the blockchain technology in the first place and are also the main contributors who maintain this technology. Also, the interests of Bitcoin miners align with the interests of blockchain core developers. Problematization in this case is the instance of blockchain core developers establishing their own interests in contributing to blockchain technology that miners also share. Both actors share the interests of economic incentives and rewards, learning about blockchain technology, and valuing the ideologies of blockchain technology. Interessement can be seen as the moment in which miners are initially interested in blockchain technology for some of the same reasons as core developers, specifically for economic incentives that blockchain itself offers and for the proof-of-work mechanism that blockchain utilizes because of its security and decentralized protocol. Once Bitcoin miners are interested, they start to participate within the community by learning about it through forums and other networks – this can be seen as the enrollment phase. Finally, the act of mobilization can be observed when miners successfully integrate themselves into the network and continuously mine for profit. The process of mining is energy intensive as described earlier in the paper, because of the complex calculations required. Miners continuously mine, gain more profit, and then buy more equipment to mine for more profit. This creates a negative feedback loop of high energy usage which causes an increase in carbon emissions.

Conclusion

There are many factors that contribute to the impact on the environment, especially with the increase in carbon emissions. However, in the case of blockchain technology, the most notable contributors include the blockchain itself, miners, and core developers. Actor-Network Theory was used to explain the reasons for the high energy usage of blockchain technology as a translation process. The blockchain core developers were the focal actors in the network as they had the most power in developing and maintaining the blockchain itself. In addition, their interests align with some of the interests of miners. The most important interests they share that play a key role in impacting the environment are economic incentives, learning about blockchain technology, and attraction for the ideologies of blockchain technology. What is crucial to note is that proof-of-work is the main mechanism that blockchain networks use because of their decentralized and secure nature and it is one of the main attractive features that miners and core developers value. However, at the same time it is a mechanism that uses high energy to continue its functionality for users. With the interests of miners and core developers in mind, this prompted miners to be initially interested in learning more about blockchain technology and thus they participate within the community. Then, they fully unify themselves into the actor-network by engaging in mining practices. After they are completely integrated into the network, they are continuously mining to gain more profit which leads to higher energy usage and an increase in carbon emissions.

Although the negative impact on the environment is significant because of the degree of usage of blockchain technology and the actors who contribute to it, there are possible ways to mitigate this issue. The first possible action that stakeholders of blockchain technology can take is redesigning the current proof-of-work mechanism so that the computational power it utilizes to validate blockchain transactions can also add benefits to its users, specifically saving costs for blockchain participants by recycling computational resources (Truby et al., 2022). A second action that can be taken is to implement policies that discourage the use of proof-of-work designs. The New York State Senate has already passed a bill with the purpose of halting proof-of-work blockchain verification methods until an environmental impact assessment takes place (Truby et al., 2022). Lastly, stakeholders can push for the use of a different blockchain mechanism that is not energy intensive. For example, proof-of-stake is an alternative consensus mechanism that uses assets or currencies as voting weight as opposed to using resource computing power (Bada et al., 2021).

It is important that stakeholders of blockchain technology understand the impact that blockchain imposes on the environment. Having a good understanding of such an issue will help keep stakeholders informed of the consequences of their contributions and will prompt them to act in mitigating this issue. It is only when there is action taken to mitigate this issue will there be a balance between the costs and benefits of using blockchain technology.

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