

The Environmental Effects of Cryptocurrency Mining in the World

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Abstract

Cryptocurrency is called as a digital or virtual currency, is included in the financial system independently of the monopoly of legal authorities and is difficult to control. Since the market value and transaction volume of cryptocurrencies is very large, it brings significant change on a global scale. Cryptocurrencies have disadvantages as well as advantages. Some of environmental impacts triggered by the cryptocurrency mining can be expressed as the high electricity consumption, the increased carbon footprint and the generation of the electronic waste. In this study, the structures of the cryptocurrency and block-chain technology are analyzed, and the amount of energy consumed by the cryptocurrency mining and its environmental dimensions (environmental and social consequences) are examined. Lastly, activities to prevent the environmental impacts of mining activities are evaluated.

Keywords: Cryptocurrency, Public Administration, Technology, Bitcoin, Environment

1. Introduction

The developments experienced in the last 50 years have been so great that they have caused a profound impact on societies and countries. Especially with the spread of the "internet" in 1993, technological developments became widespread and the internet began to change traditional systems. The presentation of Bitcoin in 2009 changed the definition and conditions of the use of money. Bitcoin can be seen as a breakthrough for the computer science field, based on 20 years of research on the cryptographic currency and 40 years in cryptography by thousands of researchers in the world. It offers a method for Internet users to transfer a unique digital property to other Internet users, while ensuring that the transfer is safe for everybody. Contracts, assets, bonds and etc. are exchanged by means of a distributed trust network which does not need or rely on a central intermediary such as banks or brokers. The owner can just send his/her own assets, recipients can just receive them, assets can just be in a place at a time, and anyone can verify transactions and the proprietorship of assets at any time (Marc, 2014). The cryptocurrency is the next level in the process of the evolution of money and can be

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thought as the electronic money that has no connection with objects of the material world. The creation of money, the distribution of money and the maintenance of money are not directed and controlled by a central bank. This system uses the software that shares peer-to-peer connection and manages exchanges like a digital wallet. It has a decentralized structure in a large community. The transfer of the currency from one wallet to another consists of coins, security accounts, debit cards, bank accounts, paper money and digital bits without requiring collateral. Cryptocurrency relies on the specialized personal computer hardware that mines new coins with the process requiring the significant computing power (Pasquale, Rana, Tarabella, and Tricase. 2017:1-2).

Nowadays, people's interest in cryptocurrencies is increasing in number due to their rapid price changes, the volatility in markets and their speculative features. For example, Bitcoin is considered as the most commonly used virtual currency around the world. There are 1565 cryptocurrencies used in today's markets. The total capital size of Bitcoin, the most frequently used cryptocurrency, is 115 billion dollars (Taş and Kiani, 2018: 370). On February 2011, the value of Bitcoin was 1 US dollar. In March 2013, the market value of Bitcoin reached 100 dollars and the transaction volume exceeded 1 billion dollars. Bitcoin has become very popular and has continued to rise regularly due to the excessive demand. The rapid value increase experienced by Bitcoin has risen regularly and broken new records, despite the experience of speculative sudden losses in value in some periods (Demartino, 2018: 42-66). However, in an uncontrolled way, people started mining with their own computer hardware, then in rooms full of processors and graphics cards, which are the main mining hardware, which accelerate the mining process, and finally with devices that only provide the mining process. This has resulted in the unbalanced and uncontrolled high energy expenditures and electronic waste throughout the world. The negative environmental effects caused by the energy consumption, carbon emissions and the amount of the electronic waste during the crypto mining raise concerns about cryptocurrencies. An average of 81% of global energy consumption is based on fossil fuels, and since the interest in the crypto mining increases, it is likely to cause serious problems in the energy consumption in the future (International Energy Agency, 2020). Although there are many studies on the financial advantages, legal recognition, use and risks of cryptocurrencies, the number of studies on the effects of the energy consumption, carbon emissions and the amount of the electronic waste resulting from the production of these digital assets on the environmental sustainability, global warming and climate changes are limited. The aim of the article is to examine the effects and possible consequences of the production chain of cryptocurrencies on environmental sustainability and to contribute to the literature by making suggestions.

In the first part of the article, basic concepts about the cryptocurrency and cryptocurrency mining are explained. First of all, blockchain technology, which is the work system of Bitcoin and alternative cryptocurrencies, is explained and the historical

background, features and the functions of the blockchain technology are examined. Then, the main algorithms that enable this technology to work are explained. The mining process that ensures the operation and the survival of the blockchain technology is explained. In the second part, the dangers caused by the mining process on the environment are explained. The environmental problems caused by mining operations in the world are examined and their environmental effects are analyzed in detail and the steps taken to reduce these effects are evaluated.

2. Cryptocurrency

Cryptocurrency can be briefly defined as a digital or virtual currency with the encryption for security purposes. Money is placed in virtual wallets through the use of passwords and is used with the same password. The feature of the crypto money is that it is used without any central authority, is closed to the intervention of countries, and cannot be manipulated (Günay and Kargı, 2018: 62; Bunjako , Trajkovska and Kacarski , 2017: 32). This feature mostly comes from the technology called as blockchain. Satoshi Nakamoto's original article titled Bitcoin in 2008 included the word of blockchain. Blockchain, the underlying technology of cryptocurrency, is defined as a block of data chained in the cryptographic form (Altay & Sumerli, 2020: 28).

In the Turkish law, when the issue of attributing the monetary value to crypto assets is evaluated within the scope of the law of obligations and the subject of the act is money, the payment with crypto assets should be accepted as an *datio in solutum* (Çon , 2022: 234). Cryptocurrencies are also defined as the virtual and digital money or crypto assets. The article 3 of the regulation by the OECD, the European Union and the Central Bank of Turkey on April 16, 2021, defines cryptocurrencies and states that: *It refers to intangible assets that are created virtually using distributed ledger technology or a similar technology and distributed over digital networks, but are not qualified as fiat money, registered money, electronic money, payment instrument, securities or other capital market instruments.*" (6493 Sayılı Ödeme ve Menkul Kıymet Mutabakat Sistemleri, Ödeme Hizmetleri ve Elektronik Para Kuruluşları Hakkında Kanun, 2013). The cryptocurrency is created to facilitate peer-to-peer transactions and is independent of any intermediary. Coins are not printed or produced physically and they only exist digitally. Since cryptocurrencies cannot be stored in the bank, they cannot be withdrawn from there, but their transfer is possible.

The only proof of the existence and ownership of the crypto money is the transaction record in the blockchain. These records contain cryptocurrency records that are distributed on the blockchain, similar to an accounting ledger, and are open to everyone. It is possible to use cryptocurrencies as a peer-to-peer medium of the exchange when there is an accounting ledger. This ledger is accessed via blockchain and personalized passwords are used. Those who prepare ledgers are called as miners. They approve the transactions by acting similar to the clearing house and update the account books by acting similar to accountants (Türk Bilişim Vakfı, 2020: 33-34). David Chaum, the first software expert of digital currencies, founded the International Cryptological Research

Institute and created the DigiCash, which is described as the first digital payment system (David Chaum personal Webpage, 2023). When the concept of the cryptocurrency is mentioned, it essentially emerged on October 31, 2008, when Satoshi Nakamoto sent an e-mail with "Bitcoin P2P e-cash paper" to "the cryptography mailing" group of a site called metzwod.com (Rodrigues, 2021). Nakamoto announced Bitcoin as the first cryptocurrency with his article published in 2008 under the name of end-to-end payment system and made history about the first digital money in a distributed database made with the encryption technology (Berentsen, 2019).

2.1. Cryptocurrency Concept

The form of money does not matter if it is used as a means of the payment and accepted by society. In this case, the expected benefit from money can also be obtained through paper, electronics or simple metals. The evolution of money started from the commodity money and progressed to the electronic virtual currencies that are popular these days. Although the virtual money is not basically money regulated by any institution or organization, it is also used as money in its traditional sense in certain situations. While defining the virtual money, the European Central Bank (2012) stated that it had no regulation, was generally controlled by those who create it, and was a money accepted by the virtual society. The digitalization of money has accelerated commercial transactions and made them safer, thanks to the rapid movement of money. Due to the existence of different ideas and definitions on cryptocurrencies, the European Parliament has categorized the definitions made by various organizations such as the European Central Bank, IMF, Payments and Market Infrastructures Committee, European Banking Authority and the World Bank, and although there is no unity for the definitions, cryptocurrencies are considered as sub-types of virtual currencies. The cryptocurrency can be treated similarly to money (in return for which goods and services can be received), but is independent of national borders, central banks, financial institutions and fiat currencies (it is not issued by the state and transactions are not intermediary). Additionally, the cryptocurrency can be bought and sold on global exchanges that operate according to cryptographic principles that ensure secure and verifiable transactions, and is based on the data sharing between users directly, without a third party such as a central server (Ertz & Boily, 2019).

2.1.1. Features of the Cryptocurrency

The cryptocurrency was born as a digital asset that is secure and transferable with the help of cryptography, and the popularity of Bitcoin increased especially in 2011, and following the increase in this popularity and recognition, alternative crypto currencies began to emerge (White 2015: 383-384). The crypto asset was first designed and implemented as a solution to the financial crisis. Satoshi implemented this electronic payment system, believing in the unshakable and durable nature of the cryptographic proof instead of trust in currency. The crypto asset is based on the cryptographic proof rather than trust, and two parties can transact directly with each other without a 3rd

party intermediary. Buyers can be protected by routine escrow mechanisms (Nakamoto, 2008: 1). This is the peer-to-peer electronic network that gives people the opportunity to make anonymous transactions without financial intermediaries. It was initially used for online payments in the form of the electronic cash that could be held as a means of exchange for short or long-term investment purposes or for speculation purposes. As its popularity and frequency of use increased over time, the days were used in many tasks such as business and company mergers. Since regulated capital raising processes are not implemented in this system, it is also used in Initial Coin Offerings (ICO), which are used as a quick and easy source of financing for startups (Peters, Panayi and Chapelle, 2015; Murşan , 2023: 40). Recently, the number of crypto assets has increased significantly in the world, and cryptocurrencies with more than 500 different types such as Bitcoin, Ethereum, Ripple, Litecoin and Dash have increased day by day. These assets are not tied to any authority or center, are digital in nature, cryptocurrency prices vary, and have the anonymity in use. Although there are many crypto currencies, they have some common features (Doğan and Hilal, 2021: 143);

- It has a limited range of uses and also a limited range of acceptance,
- The opportunity for public or private companies to insure crypto money is very limited.
- It is a very complex and advanced system produced with cryptology.
- It can be produced by mining,

The change and deletion of transactions is very difficult due to the structure of the system.

2.1.2. Mining

Cryptocurrencies are basically a system created by combining multiple complex technologies. The name of the mathematical problem solving in the existing blocks in the blockchain is considered as the cryptocurrency mining, and this mining is the name of the method in validating the virtual money transactions obtained after complex transactions with special software devices and hardware and subsequently rewarded with the virtual money as the outcome of the transactions. All transactions such as the Bitcoin and altcoin mining are carried out with this method. Miners carry out these transactions by purchasing electronic parts such as computer processors and graphics cards, and millions of devices that perform the transactions try to solve unique problems in the blocks in order to surpass each other. After solving the problem, they produce new virtual currencies and cryptocurrency rewards are earned in return. Rewards can be converted into the fiat currency using online exchange platforms. The cryptocurrency mining is mostly done in four different mining types (Binance Academy,2023) as the CPU, GPU, ASIC and Cloud mining.

Since the number of miners were small in the early days, it is possible to earn high amounts from mining. However, in the current situation, the number of miners have

increased, the cost has increased and the profits have decreased. While miners ensure the security of the blockchain and the transfer of cryptocurrency, the transactions are documented in the distributed ledger. Because the blockchain technology is called as an open account, users have the opportunity to control their transactions (Dilek and Furuncu, 2018:96).

2.2. Blockchain Technology

The control, management, maintenance and security of data have become very important for people. Blockchain technology, which emerged to meet these needs, was introduced in 2008 and became known with Bitcoin in 2009. Blockchain is known as a distributed ledger and a distributed, shared, encrypted, irreversible and incorruptible information store. Blockchain is a digital platform utilized to store and verify all the transaction history between users of the system. From a technical perspective, it is considered as "*a database of chronologically arranged packets of transactions known as blocks*", against which a proposed transaction can be securely controlled against the integrity of a particular block (Kakavand, Kost De Sevres oath Chilton, 2017; Wright and De Filippi, 2015). It is a database consisting of blocks and questionable transactions that make blocks (Ünal and Uluyol, 2020:168).

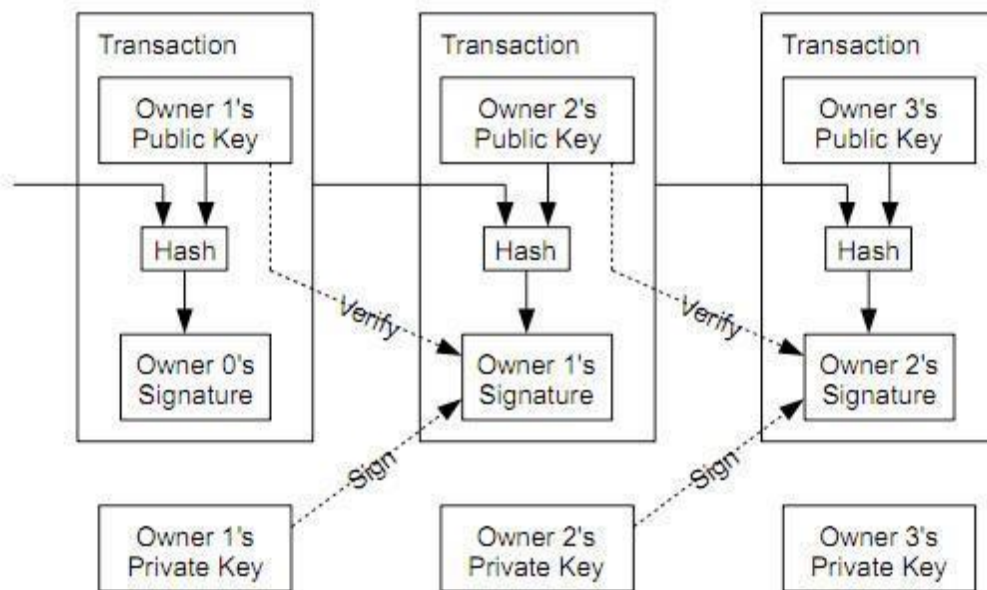
2.2.1. The Main Concept and Definition of Blockchain

Blockchain basically emerges as a specialized form of a connected list structure and can be expressed as a special connected list structure formed with hash-pointers (Ünsal and Kocaoğlu, 2018: 55). With the blockchain technology, the data is cryptographically signed and the blockchain acts as a decentralized record system where it can be stored in an agreed upon format. Blockchain is immutable and is extremely difficult for any information to change, especially if there is no network consensus (Dinh and Thai, 2018: 50). Each block has the information within itself, and this information must be linked to the previous block, which develops the chain and provides the custody. For example, by examining the blood, AI reveals what disease a person has and if this information is uploaded to the chain, other connected devices can also see the diseases that the person has. If other devices upload data from the system that analyzes blood, all devices can have the ability to use the system that examines blood. Blockchain provides transparency and accountability regarding when the user accesses their data and who accesses the data. This feature could give blockchain a huge advantage for the global notary system in the future. Additionally, blockchain stores personal and sensitive data even on diskless media, and databases have digitally signed data. Blockchain technology has the potential to seriously change today's societies and is thought to go beyond the traditional structure and contribute trillions of dollars to the global and national economy (Salah, Rehman , Nizamuddin & AlFuqaha , 2019; Önder, 2020).

2.2.2. Features of Blockchain

It has a database that is open and transparent to anyone using the blockchain, all transactions are recorded in the system, and since it is stored independently of each other by end computers within the central network structure, it can be resisted to issues arising due to central disruptions (Florea and Nitu: 2020: 67) and the accounts are numbered and numbers, and the transactions made from the accounts are seen transparently, but the owner of the transaction is not known. The use of cryptocurrencies as currency, means of money transfers and digital payment system are described as "Block-Chain 1.0". In addition, "Block-Chain 2.0" is defined as the realization of all financial transactions in the future, such as bonds, bills or loans, instead of simple money transfers. "Block-Chain 3.0" is defined as applications that can create added value in all fields such as government, health, culture, science and art, beyond financial markets and make life easier (Gediz Oral and Yeşilkaya, 2021: 216-217)

Figure 1: Blockchain Data Structure



Source: (Nakamoto, 2008: 6)

This figure shows the Block-Chain data structure and transactions are carried out by creating a new block by connecting the last link of the previous chain to the other chain, creating a new link, with the approval of the person who made the previous transaction. The first block was named 'Genesis Block'. All transactions that start with the Genesis Block are recorded in the databases of those who make transactions on the system. In case of a new transaction, all the transactions are also controlled (Gediz Oral and Yeşilkaya, 2021: 216-217). Blockchain has 3 main features (Murşan, 2023:15, Ramada, 2016; Biyan and Carda, 2021: 96-97):

1) Decentralized Distributed System:

Transactions can be made within the system without the authority of any institution or organization, and the information provided on the network is open to everyone.

2) Block Structure Immutability:

Transactions can be made within the system without the authority of any institution or organization, and the information provided on the network is open to everyone.

3) Being Safe:

Before making transactions in the blockchain, identity is checked and there are private keys that are subject to very strict conditions. Data is stored by nodes and decrypted only using private keys. Blockchain also incorporates multiple technologies and creates a comprehensive structure thanks to various applications. In a way, it can be thought of as a digitized decentralization.

3. Effects of Cryptocurrency Mining on the Environment

The cryptocurrency mining is the process that results in the production of cryptocurrencies and is carried out with the certain hardware. It is done with hardware with different features called CPU, GPU and FPGA. The selection of systems with the high transaction speed for the cryptocurrency production causes transactions to be completed faster. The miner software can start when there is a certain amount of cryptocurrency in the digital account. In the ASIC mining, the high-tech technical equipment is utilized. Mathematical problems integrated on blocks are calculated in a shorter time. Bitcoin and similar currencies produced with high calculation speed work and their production capacity are covered by ASIC mining. The most essential tool required for the GPU mining is the graphics card, and mining is completed in a faster way with high-capacity graphics cards (Aktas, 2022). The mining process may vary depending on each cryptocurrency, and the process may take longer depending on the algorithms used and the mining difficulty level of the cryptocurrency. The difficulty with the mining is the price of electricity and the price determines the profitability and incentives to involve or leave the mining market (Antonopoulos, 2017). Also, the effects of the cryptocurrency mining on the environment include the electricity consumed by the equipment, the heating of the equipment that contributes to the gradual warming of nature, the carbon footprint, the electronic waste and the gradual reduction in air quality.

3.1. The Effects of the Cryptocurrency Mining on Electricity Consumption

Energy costs are of the great importance in the cryptocurrency mining. Miners who complete the mathematical equation the fastest will have their transactions confirmed and receive a small reward in the form of Bitcoin payments. In the beginning, the mining process did not affect the amount of electricity in the states. But later, more people entered the mining business, and after large companies became involved in the mining business, this job became more difficult and caused extraordinary increases in electricity

expenses. Hundreds of thousands of computers are competing to solve the same problem, and only one of them is entitled to receive the Bitcoin fee by solving the problem, and the others do not receive any reward even though they spend energy. Most of the electricity used is wasted because 99.99% of all machines fail to win the race. It also takes a lot of time, for example more than 10 minutes per Bitcoin transaction (Rodect and Adams, 2023). It is thought that the 2023 average energy consumption of a Bitcoin transaction could be same as hundreds of thousands of VISA card transactions. Approximately 90 percent of the 21 million Bitcoins have been mined by mid-2021, and it is estimated that the last Bitcoin will be mined around 2140. As Bitcoin approaches supply limits, computational power also increases. The energy needed for mining is increasing. In 2021, Bitcoin increased over \$60,000. This was partly due to China's attempt to block domestic crypto mining since May 2021 (Best, 2023). In May 2023, Bitcoin mining consumed approximately 95.58 terawatt-hours of electricity. A Bitcoin transaction required 1,449 kWh to finish, roughly the same amount of energy that the average US household consumes in 50 days. The average cost of a kilowatt-hour (kWh) in the US is 12 cents, resulting with about the \$173 energy bill for one mining operation. Although the energy consumption per transaction was 703.25 kWh, Visa's energy consumption was 148.63 kWh. However, the energy consumption of cryptocurrencies cannot be predicted exactly. This is due to the decentralized structure of the nature of the cryptocurrency mining, the lack of the standardized recording, the existence of dynamic and continually growing mining, the diversity of energy resources and the fact that mining activities are private and secret (Kolesnikov, 2023).

Bitcoin is generally considered to be free from government control. This can be described as a valid thought in early days for the Bitcoin mining with a regular laptop. However, in days of massive mining companies, the Bitcoin mining requires plentiful sources of the cheap electricity. It is not possible for the Bitcoin mining to carry on without the plentiful electricity. Electricity supply is directed and managed by countries (Coppola, 2018). At first, states did not care about the energy consumed by mining because it did not change the level of equality and social and economic balance. However, in recent years, states have begun to react to mining. 75 percent of the mining takes place in China because of the closeness to hardware manufacturers and low electricity prices. China has put a ban on financial institutions from trading cryptocurrencies, and has tried to prevent the competition of other cryptocurrencies with its digital yuan project. the Tesla company stated that it would not accept decentralized virtual assets as a medium of payment and the severe environmental effects of the mining jeopardized the environmental sustainability (Alonso, Jorge-Vázquez, Fernández and Forradellas, 2021: 4). However, the cryptocurrency can be controlled indirectly and in a limited way. For instance, the use of traditional currencies by states is not completely free. Banks, credit card networks, and other intermediaries can control who can use their financial networks and what they can be used for. Bitcoin can be taken in a fast and easy way. An account can be opened at a Bitcoin exchange such as Coinbase. People send Bitcoin to

the digital wallet of the seller and have to wait for that transaction to be verified by the Bitcoin network. This process goes into maintaining the vast Bitcoin public ledger and is where most of the electrical energy is consumed. Miners from all over the world have competed to become the ones verifying transactions and entering them into the public ledger of the transactions. Successful miners are rewarded with newly produced Bitcoins. Bitcoin miners must purchase powerful computers and consume enormous amounts of energy to complete transactions quickly. Winners are rewarded with 6.25 freshly minted Bitcoins, worth approximately \$50,000, which is estimated to confirm a standard "block" of Bitcoin transactions. Because of the high profits of this system, many people have started mining. Although it is extremely easy to record transactions in the ledger, "trusted" computers are required to do this. It is very difficult for unreliable actors to commit fraud because it requires them to have majority power. Mining cryptocurrencies thus transforms electricity into security, but these processes cause a large amount of energy waste (Huang, O'Neill and Tabuchi, 2021).

3.2. Effects of the Cryptocurrency Mining on Carbon Footprint

Global climate change is changing the temperature values of our planet. Some of these changes have occurred due to humans. The damages caused by humans to nature has filled the atmosphere with carbon dioxide and other heat-trapping gases. Increasing temperatures on Earth cause glaciers to melt, sea levels to rise, and destructive weather situations to increase. Climate change directs people's daily lives by affecting agriculture, energy use and public health. In addition, global warming will reduce productivity, cause mass migration, reveal security threats and negatively affect economic growth. The attention to cryptocurrencies in the last few years began to make the negative features of Bitcoin visible. The Bitcoin network consumes the high amount of electricity for mining. Many scientists claim that every year Bitcoin networks can produce approximately over 100 million tons of carbon dioxide (Othman and Dob, 2022:5-6). Carbon emissions constitute almost 75% of greenhouse gas emissions and cause the global temperature to increase by 1.5 °C. The issue of carbon emissions is at the center of the problem in determining the steps to be taken within the scope of combating climate change. Thus, economic sustainability has become a global priority in the last two years and has attracted the attention of environmental academics, policy makers and international organizations in various countries for decades (Khezri et al., 2022). It seems that a consensus has been reached that the first step to be taken to prevent CO₂ emissions is to reduce fossil fuel use and energy consumption. The cryptocurrency mining, which has received increasing attention especially in recent years, requires a high amount of energy due to its production structure. For this reason, it has become one of the important areas of discussion on environmental issues such as carbon emissions. In the research conducted by Kohler and Pizzol (2019: 13598), Bitcoin networks spent 31.29 TWh with a carbon footprint of 17.29 MtCO₂-eq. Additionally, Mora and colleagues (2018) expected that the processing for Bitcoin networks can cause the increase of a 2°C

in global temperatures by 2050. The increase in carbon footprint is not only related to the high amount of electricity consumed, but also from which sources the amount of electricity consumed is obtained. Electricity consumption in mining causes a high increase in carbon emissions. Carbon emissions per transaction was 162 kg CO₂ at the end of 2017 and it increased to 545.03 kg CO₂ in the middle of 2021. The electricity consumption per transaction for Bitcoin production was 1,147.43 kWh. For Ethereum, the electricity and carbon emissions per transaction in 2021 were 77.7 kWh and 36.91 kg CO₂. On an annual basis, carbon emissions for the Bitcoin production was 52.66 Mt CO₂. It is same as the overall of carbon emissions occurred in Sweden. The yearly electricity consumption for Bitcoin was 110.86 TWh, almost same as the energy consumption in the Netherlands (117.10 TWh) (Yılmaz and Kaplan, 2022:161). Compared to traditional online banking, one bitcoin are equal to the carbon footprint of 330,000 credit card transactions (Lindwall, 2022). Krause and Tolaymat (2018) state that mining activities for 4 cryptocurrencies (BTC, ETH, LTC and XMR) mined between 2016 and 2018 were liable for 3-15 million tons of carbon dioxide emissions.

3.3. Effects of the Cryptocurrency Mining on Electronic Waste

Damages to the environment as a result of human activities such as production and consumption went unnoticed for a while, thanks to nature's ability to renew itself. However, due to the quantitative and qualitative increase in environmental pollution over time, the environment could not recover and began to deteriorate. (Büyükkelik, 2008:20). In recent years, waste generation has increased dramatically worldwide in recent years without any signal of slowing down in the future. By 2050, the global municipal solid waste production is estimated to escalate by approximately 70% to 3.4 billion metric tons. China is liable for the largest share of the universal municipal solid waste (over 15%), and the U.S. is the largest waste producer in terms of population. When considering "the special waste" (hazardous, e-waste, agricultural, industrial waste and etc.), the largest producer of municipal solid waste is the United States (Alves, 2023). More than 40 million tons of electronic waste is produced every year. But this is also a problem that predates Bitcoin, and Bitcoin only contributes to a small part of the problem (Bitcoin Magazine, 2021). Also, Bitcoin has started to produce e-waste at an alarming rate in recent years. Bitcoin's growing energy consumption raised serious doubts about the sustainability of the virtual currency. E-waste poses an increasing threat to the world, from heavy metals and toxic chemicals to water and air pollutions. Bitcoin's e-waste reached 30.7 metric kilotons per year on May 2021 (Vries and Stoll, 2021). Electronic waste generally refers to discarded computer equipment and electronic items. According to the research, a single transaction on the Bitcoin network creates 272 grams of electronic waste (Young, 2021). The UN stated that e-waste was the world's fastest-increasing waste stream, expanding 21% between 2014 and 2019 to 53.6 million metric tons, of which below a fifth is recycled. As of May 2021, San Francisco produces some 30.7 metric kilotons of e-waste each year due to Bitcoin mining (The Economic Times,

2021). The Bitcoin network processed 112.5 million transactions in 2020 (compared to 539 billion transactions processed by traditional payment service providers in 2019), with each transaction generating "at least 272 grams of e-waste." This is equivalent to the weight of two iPhone 12 minis (Hern, 2021).

4. Activities to Prevent the Environmental Impacts of Mining Activities

Problems that had not yet emerged when cryptocurrencies first appeared began to emerge later. This is due to the late realization of the value of cryptocurrencies and the profits that can be obtained from them. However, people's excessive interest in the cryptocurrency mining has also brought environmental problems. Steps are being taken or planned to be taken by countries in different ways in order to reduce or eliminate the environmental impacts of the mining process, which refers to the production of cryptocurrencies. China and the United States are the places where the cryptocurrency mining is most concentrated. Cryptocurrency miners prefer places where electricity is cheap. However, China realized the risks posed by cryptocurrencies and ordered the closure of 26 mines in Sichuan, known as the second most intensive mining region in the country. Inner Mongolia and Quinhai provinces, which are sparsely populated but rich in coal or hydropower, have also ordered the closure of all cryptocurrency mines (Euronews, 2021). Due to the negative impact of the cryptocurrency mining on the environment, Iran issued regulations against the cryptocurrency mining, banned the cryptocurrency mining for four months, and announced that this activity draws more than 2 gigawatts of energy from the national electricity grid every day (BBC, 2022). Kosovo has faced the worst energy crisis in the last decade due to production cuts and has imposed a ban on the cryptocurrency mining in order to reduce electricity consumption. Faced with outages at coal-fired power plants and high import prices, authorities were forced to impose power cuts (Reuters, 2022).

There are various strategies that can be used to lessen the environmental effects of the Bitcoin mining. The most rational step that can be taken at this point is to follow a more technologically innovative approach and turn to crypto mining using renewable energy sources rather than fossil fuels. This will reduce dependence on fossil fuels and lessen greenhouse gas emissions. Another approach is to increase the efficiency of Bitcoin mining hardware. This would reduce the amount of energy required to verify transactions on the network and could also reduce the need for cooling systems. Also, Bitcoin mining could be used to support other environmental initiatives. For example, miners could be incentivized to plant trees or invest in renewable energy projects in exchange for rewards in Bitcoin or other digital assets (Bitget, 2023).

- So as to guarantee the endurance of the use of cryptocurrency, it is first necessary to change the type of energy source used. One of the solutions put forward to reduce the environmental effects of the cryptocurrency mining is to perform the cryptocurrency mining with renewable energy sources. Nearly a quarter of the cryptocurrency miners utilize water to power installations, and hydropower

accounts for 23.12 percent of the total energy used in the cryptocurrency mining. Wind is utilized to produce the power for 13.98 percent of the cryptocurrency mining, and nuclear and solar account for 7.94 percent and 4.98 percent of the total power respectively utilized in the cryptocurrency mining. Approximately 2.40 percent of the cryptocurrency mining uses other renewable energy sources. After all, nearly 52.4 percent of the cryptocurrency mining relies on the renewable energy for the power needs (Jafri, 2023). Renewable energy sources, unlike traditional energy sources, cannot be produced continuously. However, since the energy produced during periods of low consumption at night is often wasted, this excess energy can be stored and used by converting it into digital currency. Some Canadian companies have taken steps to transfer renewable energy into bitcoin mining operations. For example, Toronto-based Hut 8 Mining has a partnership with a local company to use surplus hydroelectric power. Bitfarms, a Canadian bitcoin mining company, mines its facilities using hydroelectric energy from nearby dams. Exxon mines bitcoins with excess energy from fossil fuels. Additionally, areas in need of heating, such as greenhouse areas, can benefit from Bitcoin mining as a low-cost heat source. For example, in Canada, a greenhouse owner used ASIC devices instead of heaters to provide greenhouse heat (Seyhan, 2023).

- In case of Bitcoin Mining activities, deterrent penalties are imposed, which may include financial penalties and, in some cases, imprisonment. For instance, people or companies that mine the illegal cryptocurrency in Hong Kong can be fined up to \$500,000 or imprisoned for five years (Berman, 2019). However, due to the nature of the cryptocurrency mining, there is not enough data on where and how it is done. For this reason, mining activities can continue even if there are restrictions in these countries. The cryptocurrency mining ban is not the solution. Because it is difficult to understand that cryptocurrency mining is taking place, and people doing this secretly can cause greater damage to the environment. Instead of banning the cryptocurrency mining, companies that want to mine can be controlled by licensing. For instance, Iran had issued more than 1,000 crypto mining licenses across the country under past regulatory rules. Iranian authorities announced that nearly 6,914 illegal crypto mining farms were closed in May 2022 (Küçükkel, 2022). In this way, by licensing cryptocurrency miners, countries know where, how much, how and with what equipment miners mine, and when necessary, they can cancel their licenses and stop mining activities. In addition, energy-saving minimum standards should be imposed on the hardware, equipment and cooling systems used in excavation work. In addition, the regulation of allocating environmental share from mining profits can have a positive effect, reducing the environmental impact, and investing in the environment can be made with the environmental share collected (Yavuz, 2023: 85-90).

Conclusion

Cryptocurrencies started to come to the fore in 2008. Cryptocurrency has been called digital or virtual currency and is difficult to control because it is included in the financial system independent of the monopoly of legal authorities. Cryptocurrencies are important on a global scale due to their very high market value and transaction volume. Crypto exchanges are not the only way to own cryptocurrency. It is also possible to earn money by mining cryptocurrency. Cryptocurrencies have attracted the attention of many people with their recent development in financial markets. In addition to being an investment and payment tool, this digital money has the opportunity to earn money through the cryptocurrency mining, which has enabled this virtual money to reach large masses. Today, 81% of energy consumption has been provided by fossil fuels. The cryptocurrency mining using energy obtained from fossil fuels has caused great harm to the environment. Since it is currently very difficult to prevent the cryptocurrency mining, the use of alternative energy sources can contribute to the environment. In addition, especially those who mine crypto money go to places where electrical energy is cheap and there is concentration in these places. Some states are disturbed by this situation and ban or restrict cryptocurrency mining (Yılmaz and Kaplan, 2022:167). Also, crypto investment scams and fake applications have become major problems in South Africa and the Asia-Pacific countries. In Europe, scammers have been found to threaten to reveal victims' browsing history on adult websites unless they provide a private key or send cryptocurrency (NDM News Network, 2023).

The cryptocurrency mining refers to the reward of high-capacity computers with new crypto money after producing crypto money or approving the money transfer and processing it in the common ledger. In particular, Bitcoin experienced a record rise in 2020, reaching 63 thousand dollars (BBC, 2021), and increased the interest in cryptocurrency mining. The interest in cryptocurrencies and the money earned from the mining in the early days have encouraged people for the cryptocurrency mining. Later, the difficulty of finding computer hardware, electricity consumption and its impact on the environment have caused the intense debate about the cryptocurrency mining. Especially since the cryptocurrency mining is done without any supervision and control mechanism, it is difficult to obtain data such as electricity consumed, carbon footprint and electronic waste. However, data obtained from researchers shows that the damage caused by cryptocurrencies to the environment is great. Certain ways can be tried to reduce the environmental impacts of the cryptocurrency mining. For example, a more technologically innovative approach can be followed and renewable energy sources can be used instead of fossil fuels. This reduces dependence on fossil fuels and causes greenhouse gas emissions to decrease. Additionally, the environmental damage can be reduced by increasing the efficiency of cryptocurrency miners' hardware. However, states can take precautions against the cryptocurrency mining, impose various restrictions, or the environmental damage caused by the cryptocurrency mining can be

eliminated with a special tax. Taxes collected can be used to protect the environment. It is necessary to regulate the cryptocurrency mining in order to reveal the scope and effects of the cryptocurrency mining and at the same time reduce its environmental impacts. Briefly, countries should reduce the negative effects of the cryptocurrency mining on the environment by taking steps to reduce negative environmental impacts, such as licensing the cryptocurrency mining, encouraging renewable energy, receiving an environmental share from mining revenues, and producing energy from the heat created by the mining process and hardware. Such measures taken by countries will reduce the negative effects of the cryptocurrency mining and make it easier to control the cryptocurrency mining.

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