Bitcoin Mining and Its Environmental Effects

Şerif DİLEK*
Yunus FURUNCU**

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Abstract: Bitcoin, with its market value among cryptocurrencies and being the biggest in terms of its processing volume, carries great potential in terms of low cost, speedy processing and low-level risk while also bringing with it important global-level change and transformation. On the other hand, the fact that cryptocurrencies and Bitcoin specifically are new, of unclear legal status, and carry the risk of being involved in illegal activity, there is the potential for their use as an extremely volatile and speculative investment tool and have environmental effects. This study examines Bitcoin mining and blockchain technology and investigates the high amounts of energy consumed by Bitcoin and its environmental effects. It is argued that the energy consumed as a result of increased Bitcoin mining will have environmental and social consequences, such as global warming and climate change.

Keywords: Cryptocurrencies, Bitcoin, Energy, Environment

Bitcoin Madenciliği ve Çevresel Etkileri

Öz: *Kripto paralar içerisinde sahip olduğu piyasa değeri ve işlem hacmiyle en büyük para birimi konumundaki Bitcoin düşük maliyet, hızlı işlem ve taşıdığı az risk boyutuyla büyük bir potansiyeli taşımakta ve küresel ölçekte önemli bir değişim ve dönüşümü de beraberinde getirmektedir. Öte taraftan, Bitcoin özelinde kripto paraların henüz yeni, yasal statülerinin belirsiz ve yasa dışı işlemler için kullanılma riskleri ile birlikte aşırı volatil, spekülatif bir yatırım aracı olarak kullanılmaları ve çevresel etkileri bulunmaktadır. Bu çalışmada, Bitcoin madenciliği ve blockchain teknolojisi incelenmekte, Bitcoin'in tükettiği yüksek miktardaki enerji ve bunun çevresel boyutları irdelenmektedir. Bitcoin madenciliğinin artış göstermesi sonucu tüketilen enerjinin küresel ısınma ve iklim değişikliği gibi çevresel ve sosyal sonuçlarının olacağı vurgulanmaktadır.*

Anahtar Kelimeler*: Kripto Paralar, Bitcoin, Enerji, Çevre*

I. Introduction

In the past few years, there has been increased interest in Bitcoin's usage and as an investment tool. During the global financial crisis when people experienced a loss of trust, Bitcoin appeared as a potential answer to this trust crisis with its mathematical certainty dependent on blockchain technology. Bitcoin is defined as an electronic payment system of digital value with a direct, anonymous, secure, economic, fast, non-central and encrypted web. The biggest cryptocurrency due to its market value and its processing volume, Bitcoin affords great advantages to its users by separating itself from traditional bank transfers.

* Dr., Researcher SETA Foundation for Political, Economic and Social Research, Author for corresponding,

** Assistant Professor, Kocaeli University, Department of Administration and Organization

Bitcoin and other cryptocurrency are not under the control of any institution or government as other fiat money are when using blockchain technology. The creation, change and inspection of Bitcoin, which uses a developed technological infrastructure, is done through the use of cryptographic principles and a software algorithm. With the appearance of Bitcoin, cryptocurrencies referred to as altcoin also appeared on the market in the thousands. When considering cryptocurrencies superficially, they appear highly volatile and open to speculative use. Attracting the attention of users and investors, while cryptocurrencies are independent in the sense that they can be used for money laundering and illegal activities, they are dependent when it comes to government decisions about Bitcoin and its environmental dimension.

There are varied opinions on Bitcoin as a cryptocurrency. These opinions can be divided into two: (i) optimistic opinions that emphasize the advantages of Bitcoin, and (ii) pessimistic opinions where Bitcoin's disadvantages are predominant. The basic arguments of those with a more optimistic approach to Bitcoin is that Bitcoin is based on a sturdy technological/cryptographic basis and that it cannot be manipulated. Those who are pessimistic argue that because it lacks a specific center, it could cause a *'balloon-lunacy'* financially which would lead to environmental damage due to the energy it consumes. Those who are in the first group state that there should be specific inspections and regulations brought on cryptocurrencies due to their positive approach to digital currencies, Bitcoin in particular, and that the system must be placed on a more legal base. Moreover, they state that even if small in scope, *Bitcoin Exchanges* should be established in order to monitor, inspect, and ensure that processes occur in a legal framework. Another fundamental argument is that as long as the system is based on a legal foundation -and as long as it functions properly- governments can also profit from the market through taxation. Those in the second group state that Bitcoin and other digital currencies should be avoided, and that there should be no integration with this system because it is used to launder money.

Following a literature review, arguments tend to focus on whether Bitcoin is a balloon or a commodity, a currency or a financial investment tool, and lately, about Bitcoin's energy consumption. Studies have been done on Bitcoin's use as an appropriate tool to diversify portfolios, its use as a hedge against the dollar (Dyhrberg, 2015; Bouri et al, 2016), and a preference for it more as an investment tool than as alternative payment (Glaser, 2014). Another piece points out Bitcoin as both a speculative and a standard financial existence due to its unique structure (Kristoufek, 2015). In another work comparing Bitcoin's volatility with that of other investment tools, it is argued that the Bitcoin market is extremely speculative (Baek and Elbeck, 2015). The biggest criticism of cryptocurrencies is their proclivity for being used for

illegal activities such as money laundering. Alongside this, it is emphasized that cryptocurrencies and Bitcoin in particular create opportunities for tax evaders and can replace tax havens (Mariani, 2013). In this sense, works that evaluate Bitcoin more as a speculative investment tool rather than as an alternative currency are in the majority (Baur, Hong and Lee, 2016; Dorfman, 2017). As there have not been many works done on the effects of Bitcoin's energy consumption and its effects on the environment, this study hopes to contribute to an increase in works done on this topic.

Bitcoin has recently been much on the news be it due to its value or its energy consumption. The rising levels of its energy consumption and the fact that this consumption will continue to increase brings with it a host of negativities. The dependence of nearly 80% of the world's energy consumption on fossil fuels and that this situation is not likely to change in the future brings with it serious problems for the environment. The enormous levels that Bitcoin's energy consumption will reach is regarded as a catalyst that will finish off finite fossil reserves. Bitcoin mining spreading in areas where electricity is provided through burning coal causes the already low air quality in these areas to further worsen. In this study where we examine Bitcoin mining and blockchain technology, the energy Bitcoin consumes and its environmental consequences have been emphasized. The energy consumed due to increased Bitcoin mining is put forward as one of the most important problems impeding Bitcoin's development.

II. Cryptocurrencies: Bitcoin and Altcoins

The 2008 global financial crisis caused many changes in the global financial system. The economic crisis that occurred on the global level and the collapse of trust in central banks and financial institutions triggered the appearance of cryptocurrencies as alternative (Dahan and Casey, 2016). In this process, while countries' stock exchanges were collapsing, credit rating agencies lost their repute; as financial institutions and companies neared the verge of bankruptcy, big banks tanked. However, even more than all of this, people's belief in the financial sector was seriously damaged. As such, Bitcoin as a cryptocurrency first appeared in an article called *Bitcoin: A Peer-to-Peer Electronic Cash System* that was published a short period after the global financial crisis. This article described Bitcoin as an electronic payment system where the two sides are directly connected to each other over an encryption; critiquing the mediation services provided by banks, this article also stated that – keeping in mind the rising trend of e-commerce – there was no longer a need for banks to carry out payments (Nakamoto, 2008).

Following Bitcoin's introduction to the market and rising demand for it, thousands of digital currencies appeared. While various digital currencies such as Litecoin, Namecoin, Swiftcoin appeared after Bitcoin, Ethereum, Ripple, Bitcoin

Cash, Litecoin, Cardano and IOTA are being used in the market as the most popular currencies after Bitcoin. These cryptocurrencies are referred to as altcoin (alternative coin) because they were developed after Bitcoin. Bitcoin appeared in 2008 and entered the market in 2010, at a value of $0.07. Up until the beginning of 2011, its maximum value had risen to $1; Bitcoin later embarked on 2017 with a value of $960 and, demonstrating an amazing performance throughout the year, rose to nearly $20,000. Bitcoin's swift appreciation in such a short period was presented in the global agenda as "digital/virtual gold." The alluring performance by Bitcoin caused many people to shift their investments to cryptocurrencies. The rising interest in cryptocurrency and the resulting increase in demand for Bitcoin meant an exponential increase in market volume and price.

As of January 2018, there are 1467 cryptocurrencies, active in 7926 market, with a total market value of 493 billion dollars and an approximate daily volume of 30 billion dollars. Bitcoin is the biggest among these cryptocurrencies due to its market volume, number of users, and its acceptance by certain companies and corporations. Leaving aside the market shares of all cryptocurrencies, Bitcoin alone has a market share of nearly 35% with a market size of 171 billion dollars and a market volume of 16 million 800 (coinmarket.com). Bitcoin was established at a capped supply of 21 million. On the condition that the system works correctly, the maximum amount of Bitcoin in circulation in 2140 would reach 21 million, and Bitcoin's growth rate – according to the present algorithm – would converge on zero and its supply would be reset to zero after 2140 (Ciaian et al., 2016).

The limit to Bitcoin's supply shows that the appreciation which has recently occurred due to rising demand is inevitable. The aim behind keeping Bitcoin's supply limited was to ensure that it would be processed like money in exchange for gold. Bitcoin's price is determined based on the supply-demand relationship in the markets where it is involved. However, while Bitcoin's exponential appreciation in the past few years surpassed the aim of its appearance, its extreme fluctuations have also caused it to be regarded as a speculative investment tool. Causing losses to investors and users, these fluctuations have caused the thesis about Bitcoin as a balloon to be much more apparent.

Easy to use, Bitcoin can be quickly bought or sold and transferred. Harboring a developed technology called blockchain, cryptographic principles are used in Bitcoin's formation and to inspect its change. Bitcoin's most important distinction is that, in comparison to standard fiat money such as the dollar or the euro, is that it is solely controlled by a software algorithm that is not overseen by a person, group, company, central authority, or administration. Despite not being depth of market enough, Bitcoin and other cryptocurrencies are highly volatile and open to speculative use due to their high returns. Alongside this, their availability for use in

money laundering and illegal activities makes them as dependent as they are independent.

As Bitcoin's acceptance as a payment tool on international platforms spreads, the number and diversity of operations accepting Bitcoin has increased. In this sense, Bitcoin's widespread use increases over both the internet and in shopping, and shows itself in the rising number of ATMs and the number of operations that accept Bitcoin. As such, alongside Bitcoin becoming popular as a digital currency, it also serves physically through ATMs set up in various parts of the world. Currently, there are 2098 Bitcoin ATMs in 62 countries, and over 11,500 businesses accept Bitcoin as a method of payment. All of the ATMs in question (100%) not only serve Bitcoin, some of them also serve altcoins. Nearly 60% of ATMs that provide Bitcoin services are in the US. When considering its spread among continents, 96% of ATMs are in North America and Europe. Asia's share in the number of ATMs is only 2.4% (coinatmradar.com). From this, it is observed that Bitcoin is spreading much faster and reaches more users in the Western world.

III. Blockchain Technology and Bitcoin Mining

Following the global financial crisis and people's crisis of trust towards the financial world, the appearance and timing of a technical analysis about Bitcoin in this period as an alternative currency attracted attention. In this analysis, how the infrastructure of cryptocurrencies – referred to as blockchain technology – is formed and works is detailed. The important point emphasized by the study as the greatest character of cryptocurrencies was its claim that a new type of trust was being established based on mathematical rules and computer algorithms over the phenomenon of trust towards authorities with the power to print money.

Despite being previously known, blockchain technologies came to the fore with Bitcoin through a new concept. Blockchain is a constantly-growing, distributed database where records are connected to each other through cryptographic elements (hash functions) (Piscini et al., 2017). Its most important specialty is that while there is no central system, all data is stored by users that are integrated to the system. A distributed database that allows for following encrypted processes, blockchain is referred to as the distributed general ledger (Distributed Ledger Technology-DLT) (Collomb and Sok, 2016). By removing the need for a mediator between the two sides, blockchain technology and cryptocurrencies replace the need for trust with a technology of mathematical certainty and point to this operating as a trust mechanism as well (*The Economist*, 31 September 2015). Here, the focus is on the trust provided by the security of cryptocurrencies with blockchain technology.

With the capacity to operate as a digital storage facility, blockchain is a valuable technology that can also be applied in many different areas, including the proof and storage of real estate, vehicle and valuable assets; birth, marriage, and death certificates; holding elections; managing smart contracts; saving, processing and managing financial documents. Through digital identities, blockchain technology allows individual users an unprecedented opportunity for control. Not limited to cryptocurrencies and the financial sector alone in this way, blockchain, as part of the capabilities provided by digital technology, are transformed into opportunities used by businesses.

Bitcoin production, described as creating money, is referred to as mining. In the period when Bitcoin first appeared, because there was a small amount of people who were mining, it was possible to create high amounts of Bitcoin in a short period of time. In the current situation, however, the system becoming harder and the increase in the number of miners has made production difficult and very costly. Drawing similarities with mining for gold, in this case mining is used both to confirm processes and to define the people who have put it on record. In this sense, Bitcoin production and recording and confirming processes in blockchain are done by miners. While miners ensure the security of the blockchain system and the transfer of cryptocurrencies, the transactions they carry out get recorded in the distributed ledger. As blockchain technology is a open account, all users can check on their transactions.

Through the electrical energy they use and in exchange for their services of confirming and recording to the system – which creates new Bitcoin and is put into circulation – the Bitcoin that is now in circulation goes back to the miners' own pockets. In a sense, as a result of the mathematical operations they do, miners not only produce new Bitcoin but by carrying out the services needed by pending transactions, they gain Bitcoin. Thus, the energy spent and services provided physically by miners not only helps circulate Bitcoin, it also means they make earnings. However, while mining was simple when Bitcoin first came out and its use was easy, mining now is less profitable and carries a more difficult dimension. In its current state, the user and investor interest in Bitcoin and the gradually increasing difficulty of processing has meant that individuals and institutions are increasingly investing in extensive and expensive machines dedicated solely to mining Bitcoin in key depots (Vigna and Casey, 2016).

IV. Bitcoin Mining in Global Energy Consumption

Nearly 80% of all global energy consumption is through fossil fuels. The fact that this is unlikely to change in the short term and that the importance of fossil fuels will continue in the future is clearly explained in Table 1 below. While there have been recent positive developments in alternative energy, it has yet to reach a level

that meets global energy needs. In the table, it is predicted that the energy acquired from coal will decrease slightly by the year 2045 while there will be an increase in the usage of natural gas.

Table 1. *Global Energy Consumption Based on Energy Source (Precentage)*

Years	Oil	Natural Gas	Coal	Nuclear	Biomass	Hydro	Other Renewable
2000	37,74	21,39	21,88	6,49	9,62	2,16	0,72
2010	33,65	21,93	26,09	5,48	9,26	2,27	1,32
2015	33,69	21,99	25,71	4,79	9,57	2,30	1,95
2025	32,81	23,66	23,66	5,52	8,83	2,52	3,00
2045	31,95	25,39	20,40	7,28	7,99	2,57	4,42

Source: Exxon Mobil, 2017 Outlook for Energy: A View to 2040, p.44

Mining, dependent on the solution of a complicated crypto-puzzle, requires an exorbitant amount of computer power. The main cost of Bitcoin mining is the energy expended to ease the work of accounting done while mining. Internet, hardware maintenance, cables, etc. are all lower than the energy costs (Hayes, 2015: 2). According to a study from 2014, it is calculated that Bitcoin consumes as much energy as Ireland (O'Dwyer and Malone, 2014). When comparing countries' electricity consumption and the energy consumed by Bitcoin mining, Bitcoin mining surpasses 175 countries in total, more than 20 European countries included, in terms of electricity consumption. Thus, the amount of energy used up for mining Bitcoin is more than the energy consumption of many countries. If considered within a sequence of countries, Bitcoin comes in 50th in terms of the amount of energy it consumes. In a case where 400 transactions are done per second, it has been calculated that Bitcoin mining requires 30,582 MW of energy per month (Mishra, 2017).

Power Compare, a UK-based energy price comparing platform, points out that Bitcoin production has been one of the significant causes for rising energy consumption across the world in the past couple of years. In its report, *Power Compare* states that by November 2017 after recording an increase of approximately 30%, Bitcoin's average yearly energy consumption had reached 32 TWh. By the end of 2017, Bitcoin's average energy consumption had reached 37 TWh (*Digiconomist*, 2017a).

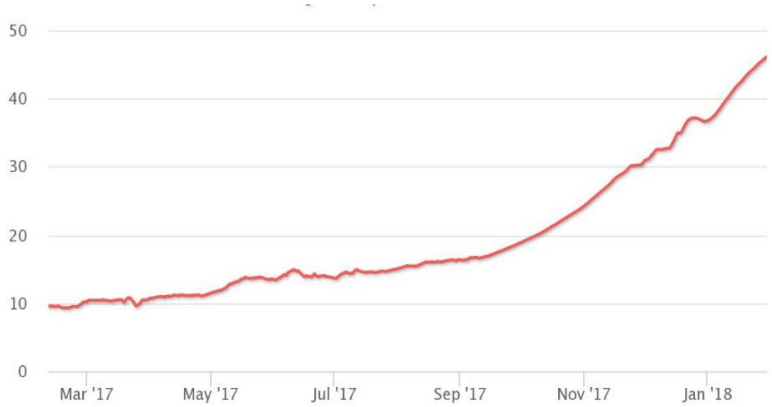

Figure 1. Bitcoin Energy Consumption (TWh/Year)
Source: Digiconomist

As can be seen in Figure 1, Bitcoin – consuming 47 TWh of energy since January 2018 – is equal to 1% of the energy the US consumes, and a third of Holland's. This system, which recorded approximately 10 TWh of energy usage in the beginning of 2017, has experienced a four-fold increase in less than a year. Corresponding to a ratio of a thousand to two in global energy production by the end of 2017, Bitcoin emits 162 kg CO_2 per transaction (*Digiconomist*, 2017a).

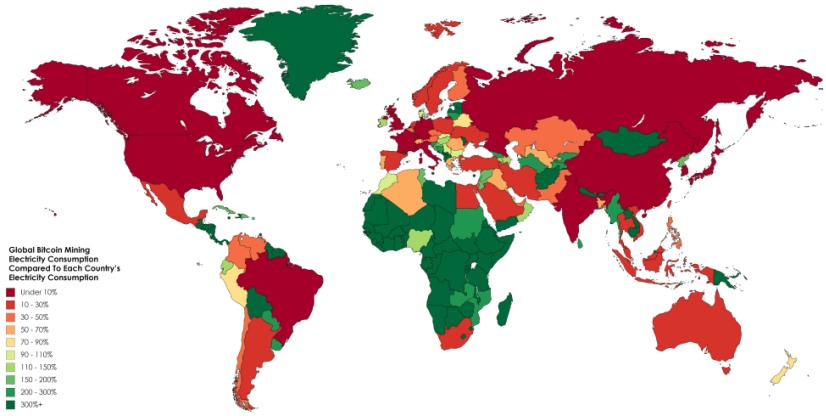

Figure 2. Ratio of Global Bitcoin Mining to Countries' Electricity Consumption
Source: Power Compare

As can be seen in Figure 2, Bitcoin's energy consumption has reached high amounts and requires more energy than most countries consume. Except for a few countries on the African continent compared to which Bitcoin uses more energy, Bitcoin's energy usage corresponds to approximately 13% of Turkey's electricity consumption. If Bitcoin's electricity consumption speed continues to rise at the same rate, it is expected that after a certain period, it will require energy equivalent to global energy consumption. The results of a research conducted by Citigroup contends that if the amount of electricity required by the Bitcoin system continues and rises, the Bitcoin system is likely to collapse (Hypo, 2017).

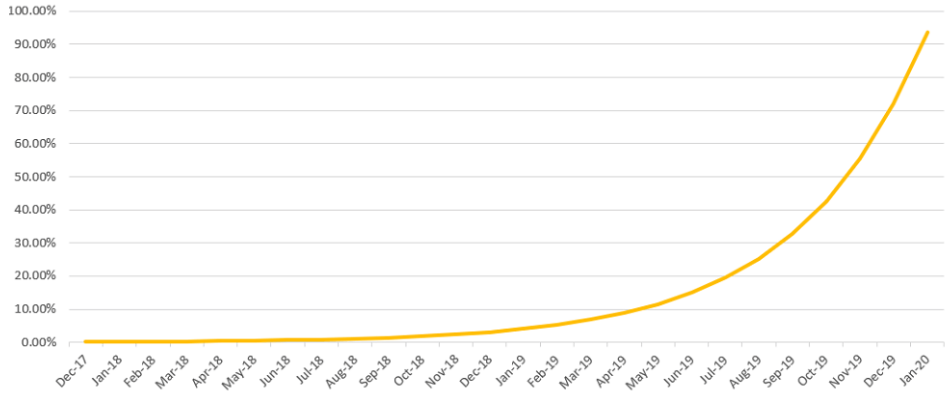

Figure 3. Growth of Electricity Consumption in Bitcoin Mining
Source: Power Compare

The above figure shows the pattern of energy consumption throughout 2017 for Bitcoin transactions, where consumption tendency has risen exponentially towards the end of 2017. In *Power Compare*'s report, it is stated that by the end of 2017 Bitcoin had used up more electricity than 150 countries (Holthaus, 2017) and that it had consumed 462 MW of energy to ensure the security of the blockchain system (Hileman and Rauchs, 2017). If Bitcoin's energy consumption rate increases as shown in Figure 3, it is expected that Bitcoin will use more electricity than the UK by October 2018. It is further predicted that by July 2019 it will equal the US' total energy consumption, and by February 2020 equal global energy consumption (*Power Compare*, 2017).

According to the Bitcoin energy consumption index, the cost of electricity consumed for Bitcoin mining is around 1.86 billion dollars. "Security" is pointed out as the reason behind Bitcoin's astronomical energy consumption. As is known, the lack of a central authority in Bitcoin transactions requires it to protect itself from

outside attacks and corruption – a task which is carried out miners (Unlu, 2017). Despite the high cost of electricity consumption and lacking energy, the solution for many users/countries who do not want to miss out on the cryptocurrency train has been to conduct mining operations in areas where electrical energy is low-cost. Due to the high prices of electricity in production and the instruments used in mining, their production in Turkey is very costly. However, for example in countries like China where both electricity and mining machines are low-cost, production is very wide-spread.

V. Bitcoin's Global Effect on Pollution

Nearly 3 million people die due to air pollution around the world every year. Following hypertension, diabetes, and smoking, air pollution is the fourth most important factor that causes risks to people's health. Just as air pollution is damaging to the environment, it also brings costs to the economy. The frequent production, use, and burning of fossil fuels in particular increases air pollution. 85% of the sulphur dioxide and nitrogen oxide emissions in the atmosphere are caused by energy production and burning (IEA, 2016a). The use of coal in electricity production is the greatest contributor to these emissions, and it is also noted that it is burning coal which accounts for 60% of sulphur dioxide emissions in the atmosphere (IEA, 2016a).

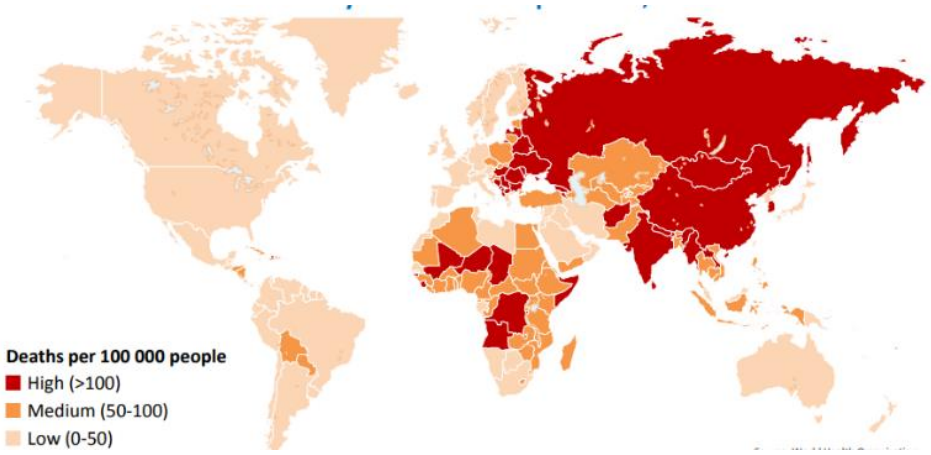

Figure 4. Death Rates Due to Air Pollution 2012
Source: WHO

It is observed that the greatest number of deaths occur in Asia (with China and India in the lead), Africa and West Europe. In Figure 4, it is shown that in cases where there is no environmental sensitivity in energy consumption, the emissions that

are caused from burning coal in order to obtain energy have a significant effect on human life. It is understood that there is a correlation between areas where there are a high number of deaths and the high amount of coal that is used.

The climate targets expressed in the Paris Agreement, whereby the increase in average global warming would be brought much lower than 2°C above pre-industry levels and the emissions from the energy sector – which cause two-thirds of global greenhouse gas emissions – would be lowered, point out how important this decrease is. Power plants that use coal are electricity plants which produce the most carbon; in order for global warming to be lowered in accordance with the Paris Agreement, the carbon emissions from coal plants must be decreased (IEA, 2016b).

It is expressed that for every search done in Google, 0.5 gr of CO_2 emission is produced. Europe has brought an emission standard where for a 1 km drive, there is a limit of 140 gr of CO_2. It is not cars that exceed this limit but rather desktop computers which, by working an average of 8 hours per day, produce 175 kg of CO_2 emissions per year. Bitcoin mining consumes more electricity than 159 countries. If the rate it consumes electricity continues until 2020, it is expected to increase this consumption to as much as Denmark's electricity use (Naughton, 2017). The NO_x, SO_2, and CO_2 and particles caused by the burning of coal negatively affect human life and the quality of air. SO_2causes acid rain and respiratory diseases, CO_2 causes emissions as a result of burning hydrocarbons, and NO_x causes dust and respiratory tract diseases while particles lead to lung diseases (IEA, 2017).

The gradual increase in energy use of digital miners in order to produce Bitcoin today brings with it new problems. In a study done by Cambridge university, 58% of Bitcoin mining is done in China, followed by the US at 16%. Mining in China, where cheap electricity can be found, involves energy production and consumption based on coal, which negatively effects the environment. Another study done on this topic shows that a Bitcoin center in China continues to depend on coal for the energy consumed by Bitcoin mining (Walt et al., 2017; Hileman and Rauchs, 2017). This situation causes a significant rise in carbon emissions. It is also seen that Bitcoin mining has come to be listed as among the reasons for emissions in the world and that the dimensions of mining's energy use is increasing day-by-day (Irfan, 2017). Another study done on this topic alleges that the biggest Bitcoin mine is in Inner Mongolia, an autonomous area in China with cheap electricity. It has been announced that the company Bitmain uses the electrical energy it needs from thermal plants in order to carry out the transactions going on with Bitcoin mining. For Bitcoin mining, in order to create electricity from 1kW of coal, 0.6-1 kg of CO_2 and for 40 mW of electricity, a total of 24-40 tons of CO_2 are produced. This is equal to the CO_2 emissions produced in one hour by a Boeing 747 commercial plane (*Digiconomist*, 2017b).

Bitcoin mining occurring in areas where electricity is obtained from coal means the worsening of air quality. Bitcoin mining is getting even more widespread with every passing day, and it is using up even more energy. In this process, it is obvious that in areas where Bitcoin is mined air quality will worsen and a significant obstruction to achieving the goals set in the Paris Agreement will form. It has been claimed that the cost and volume of the energy consumed in mining Bitcoin and its effects on the environment will be massive and that it will eventually lose its appeal due to an incapacity to continue in the same way (Holthaus, 2017). Although Bitcoin's popularity is the cause behind the speeding up of Bitcoin mining's climate change, it is also likely to be the greatest obstacle to the growth of Bitcoin mining. It is thus due to the CO_2 emissions caused by the energy consumed for Bitcoin that Bitcoin is shown as the reason behind global warming and environmental problems.

VI. Conclusion

In the past few years, cryptocurrencies have increasingly attracted the attention of users and investors. As things currently stand, Bitcoin and other altcoins are used as a speculative investment tool and the major change that is being brought about by cryptocurrencies is being ignored. This study examined the environmental dimensions of Bitcoin mining as the first cryptocurrency in terms of both its market value and volume. It is understood that nearly 80% of global energy consumption is through fossil fuels, that this view is not likely to change in the short term, and that fossil fuels will continue to be important in the future. Despite the important developments in alternative energy sources, it is obvious that the energy needs of the global economy is dependent in large part on the hydrocarbon sector. It is with this perspective in mind that the energy used up by miners during the processes of confirming Bitcoin transactions, recording them, and producing Bitcoin has been examined here. It has been emphasized that as a result of the extreme need for computer power in order to mine Bitcoin, the astronomical amount of energy used is not sustainable.

The day-by-day increase in the use of energy for Bitcoin has meant that it uses up more energy than many countries and that it harbors many dangers for Bitcoin's future. It is known that in order to avoid the high energy costs of Bitcoin mining, individuals and firms have been carrying out these operations in countries where energy is low-cost. The energy required by Bitcoin transactions and mining, which are obtained from coal and thermal plants – hydrocarbons – result in increased CO_2 emissions and cause a rise in global warming, air pollution, and even death rates. The sustainability of the environment is important for the world's development and growth, and as depicted in the Paris Climate Agreement, precautions must be taken against global warming and climate change. During such a time, the magnitude of

Bitcoin's energy consumption causes serious damage to the environment and faces us as one of the most significant obstacles in the development of Bitcoin.

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