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Sustainability of Cryptocurrency in Global Transactions

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Abstract

In the past years cryptocurrency has seen a rapid global boost in both popularity and value. Around 562 million people in the world possess some type of cryptocurrency. There have been discussions and research on the viability of cryptocurrency as a global currency in terms of transactions. The cryptocurrency with the highest likelihood to achieve this feat is Bitcoin, owing to its highest popularity, value and ownership. Notwithstanding, many more factors affect the possibility of Bitcoin emerging as a global currency. Financially, economists have analyzed possibilities like these, but the purpose of this research was to judge whether Bitcoin was a considerable option from the sustainability point of view. The primary outcome of this research has been that the amount of energy required for Bitcoin to impact the global economy as a global currency in transactions is more than what can be invested in it for the next few decades. Moreover, if we do achieve enough energy production to power Bitcoin at this level, due to simple economic rules of supply and demand, proof-of-work (PoW)technology-based cryptocurrencies will lose any actual value due to the negligible cost of the resources required to acquiring it. Hence, it is impossible to sustain cryptocurrencies like Bitcoin as a global currency in the upcoming years unless they switch to the modern proof-of-stake (PoS) infrastructure of blockchain. With major drop in energy prices, the only resource contributing to the value of cryptocurrencies would be time and the mining power (hashrates) of the ASICs (Application-Specific Integrated Circuit) involved in mining. This will further lead us down the path to total exhaustion of limited resources of silicon and induce an inflationary effect in the chipset market like what was experienced in 2020, due to hoarding and stocking of graphic cards by mining rigs around the world.However, the analysis of shortage of silicon is beyond the scope of this study.

Keywords: Cryptocurrency, Bitcoin, Energy Consumption, Proof-Of-Work, Sustainability

1. Introduction

Cryptocurrency is a rather newly-developed form of digital currency, which consists of an open and decentralized system, and uses cryptography to enhance security and to regulate the circulation of new currency tokens in the blockchain network.[1]Numerous cryptocurrencies have come into circulation today, but it all started with the creation of 'Bitcoin' in 2008 by a group of individuals or an individual under the alias of Satoshi Nakamoto- whose real identity remains secret till date. The transactions on the Bitcoin began only in the year 2009, after the release of the genesis block by Satoshi Nakamoto. The unit of this currency is a bitcoin (BTC) and the smallest unit of a bitcoin, known as satoshi after it's founder, is 0.00000001 BTC. The blockchain technology acts as a medium for the both the payers and the payee to themselves manage, regulate, secure and validate the transactions occurring at all times with

the use of an open-source system.[2] The use of blockchain also allows bringing more tokens into circulation.

“Bitcoin and similar digital currencies are called crypto-currencies by some because the underlying algorithms and security are intimately related to digital cryptographic algorithms.” (Dwyer, 2014)[3]

1.1 Blockchain

Blockchain technology is not only limited to the financial industry – it has wide application in the fields of encryption, security and database handling. However, the economic sector is seen as a primary user of the blockchain concept. This can not only be reasoned to the increasing popularity of bitcoin, but also to the substantial process inefficiencies in the current banking systems. Over the years, financial scandals and economic whirlpools have taught us that it is not always possible to identify the correct present owner of an asset (in reference to Bear-Stearns share transfer to JP Morgan Chase 2008).

Each successive block extends the blockchain, resulting in a comprehensive log of transaction history. The network can validate blocks using cryptography. In addition to the transactions, each block contains a timestamp, the preceding block's hash value (the "parent"), and a nonce, which is a random integer used to validate the hash. This approach maintains the integrity of the whole blockchain, including the first block (the "genesis block"). Hash values are unique, and fraud may be effectively prevented since modifications to a block in the chain instantaneously change the corresponding hash value.

If the majority of nodes in the network agree by a consensus mechanism on the validity of transactions in a block and on the validity of the block itself, the block can be added to the chain. this consensus mechanism ‘‘is the process in which a majority (or in some cases all) of network validators come to agreement on the state of a ledger. It is a set of rules and procedures that allows maintaining coherent set of facts between multiple participating nodes’’[4]

1.2 Cryptocurrency Mining

Mining is the integrated process of generating, transmitting, and validating cryptocurrency transactions. It ensures that the currency propagates steadily, securely, and safely from the payer to the payee. Unlike fiat currencies, which are controlled and regulated by a centralized authority, cryptocurrencies are decentralized and operate on a peer-to-peer basis. Banks that print actual cash and monitor transactions require massive infrastructure to function and run. Cryptocurrencies address this need by adopting a mining system in which network members, known as "miners" or "nodes," monitor and validate transactions that generate currency. When a transaction occurs, the details are broadcast to all nodes in the network. The transactions made over a set period of time are collected to form a 'Block'. To incorporate transparency in the system, it is designed in such a way that all the transactions made from the inception of the currency are recorded and maintained in a general ledger called the 'Block chain' which, as the name suggests, is a list of blocks created from the beginning.[1]

Mainly used keywords	Descriptions
Mining	Mining is the process of validating computations. The process adds transaction records to the public ledger of past transactions or blockchain
Hashrate	The hashrate is the unit of the processing power of the cryptocurrency network per second. The unit varies depending on the coin, usually seen as H/s.
Hard fork	A hard fork is a change to the blockchain protocol that makes previously invalid blocks/transactions valid. A hard fork requires all nodes in the community to upgrade their tools.
Blockchain	The blockchain a peer-to-peer network that sits on top of the internet. It is a public record of all transactions in order.
Monero	Monero (XMR) is an open-source cryptocurrency that focuses on privacy, security, and decentralization.
Mining efficiency	The mining efficiency of a mining device was the ratio of the number of hashes in a second, divided by the power is consumed. The unit varies depending on the coin, usually seen as J/H.

Table 1: Definitions of mainly used cryptocurrency keywords

1.3 Current Situation of Cryptocurrency

The pace at which bitcoin is mined has been devilishly predictable and unlike any other currency or asset its end-to-end supply is a known quantity and fixed in advance, not more than 21 million coins. This advantage makes bitcoin supply perfectly inelastic. Bitcoin's limited supply of coins and highly inelastic supply proves to be a major factor when it comes to handling its cost appreciation. "Kaspersky Cryptocurrency", a Moscow-based cryptocurrency firm revealed that 19% of the total world's population have bought cryptocurrencies in the year 2019 which is interesting but at the same time a study reveals that more than 81% of the world's population never brought cryptocurrencies. Only 10% of people assert they "completely understand what cryptocurrency is."

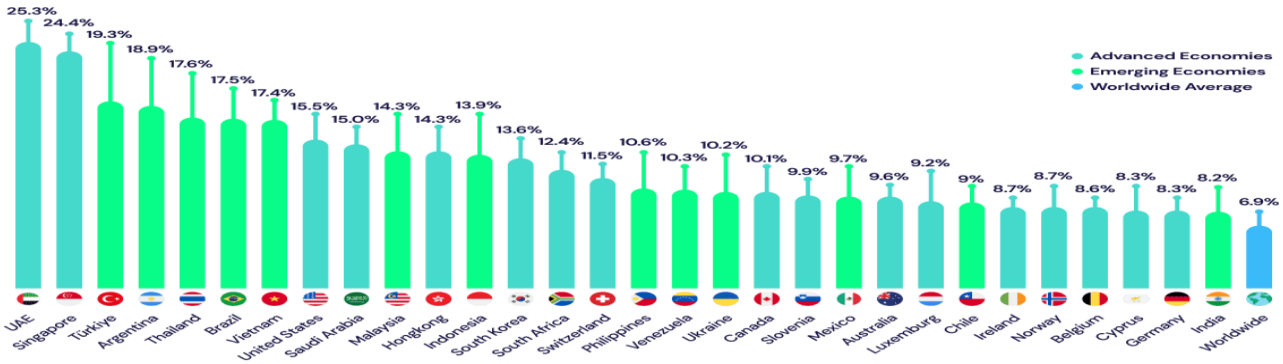

Figure 1: Percentage of Crypto Owners Globally

The figure above[5] shows the cryptocurrency ownership of major world economies. As of 2024, the estimated global cryptocurrency ownership stands at 6.8%, with over 560 million crypto owners worldwide.

Cryptocurrency has come a long way since its inception. El Salvador has adopted Bitcoin as official national currency. As of 2025, 354014 BTC (~35.1 billion USD) are traded everyday, with an average growth rate of 1.00K%. [6]

2. Inherent Problems with the Cryptocurrency System

"Everyone can create money; the problem is to get it accepted". —HymanMinsky

We are living in the midst of a transition to a new monetary system. From their introduction during the Industrial Revolution in 1800's, cash and currencies have been circulated by central banks. However, cashless societies have started to take their positions as the ideal transaction system of our daily lives. Additionally, the 2008 Great Recession, whose effects are regrettably still being felt today, was brought on by the breakdowns of the current monetary-financial system that emerged during the Great Depression. Credit booms and excessive debt have been recognized as the primary causes of financial bubbles and economic crises by both academic and institutional domains; however, few have concentrated on the financing of these booms.[7]

2.1 Cryptocurrency as a Real Asset

Characteristic	Fiat Money	Assets	Financial Assets	Cryptocurrency
Store of value	Yes	Yes	Yes	Нет
Medium of exchange	Yes	No	No	Partially
Unit of account	Yes	No	No	No
Property right	No	Yes	Yes	Possible
Economic benefits from ownership	Possible	Yes	Yes	Possible
Is a liability from a third-party	Yes	No	Yes	No
Information transfer and storage function	No	No	No	Yes

Table 2: Comparison of Currencies and their Superlatives

In the words of Prof. Dr. Frank Emmert, "The techno logy is creating a trustless environment, i.e. a financial system without the need for trusted intermediaries. In the brave new world of cryptocurrencies, there is no need for commercial banks to facilitate funds transfers, nor for central banks to issue currency and control interest- and exchange rates. There were no authorities with clearly defined supervisory powers, no guarantees by institutions or insurers, and not even rules of the road enacted by legislators or courts, when this study was started in the fall of 2021. Yet, the equivalent of US$ 3 Trillion were held by millions of individuals in the form of more than 10,000 new digital currencies in more than 200 million cryptocurrency wallets, completely disconnected from traditional bank accounts and credit cards. This sum is all the more astonishing, given the fact that every one of those 'virtual currencies' was privately created and managed."[8] Clearly, economists and financial experts are sceptical about the survivability

of cryptocurrency as a sole currency. The fact that an amount equivalent to US$3 trillion currently are in an unsupervised, open source, privately created assets, with no connection whatsoever from any international banking association forces economists to forecast upcoming economic crisis in case of the downfall of this system.According to a research paper published by the IMF in 2022, “Unbacked crypto assets are not considered to be money because they do not fulfill the three common functions of money, and regulators have broadly classified them according to their function. No internationally agreed taxonomy exists for crypto assets.” [9] Hence, it is clear that as of now, cryptocurrency is not considered to be an economically tangible method for transactions, as it does not involve any real world backing against which it can be accounted.

2.2 Volatility in the Cryptocurrency Markets

Bitcoin's design comes with a fixed supply, capped at 21 million coins, making it a **deflationary asset**. This limitation can lead to significant price swings as demand fluctuates. Increased demand from investors, particularly during times of economic uncertainty, often leads to price surges, while lower demand can quickly result in price declines [10]. The influence of media and news on investor sentiment cannot be overstated. Positive news can lead to hype, driving up prices, while negative news can trigger panic selling. This cycle of news and investor reaction contributes to the high volatility seen in Bitcoin trading. Normally, traditional market indicators like demand and the consequent supply goods or services can help us predict the shifts in fiat asset classes. However, due to relative infancy, the same cannot be said for cryptocurrency. Since stocks and commodities have existed for centuries now, we have developed specific data sets and programs to accurately predict the future of these assets.

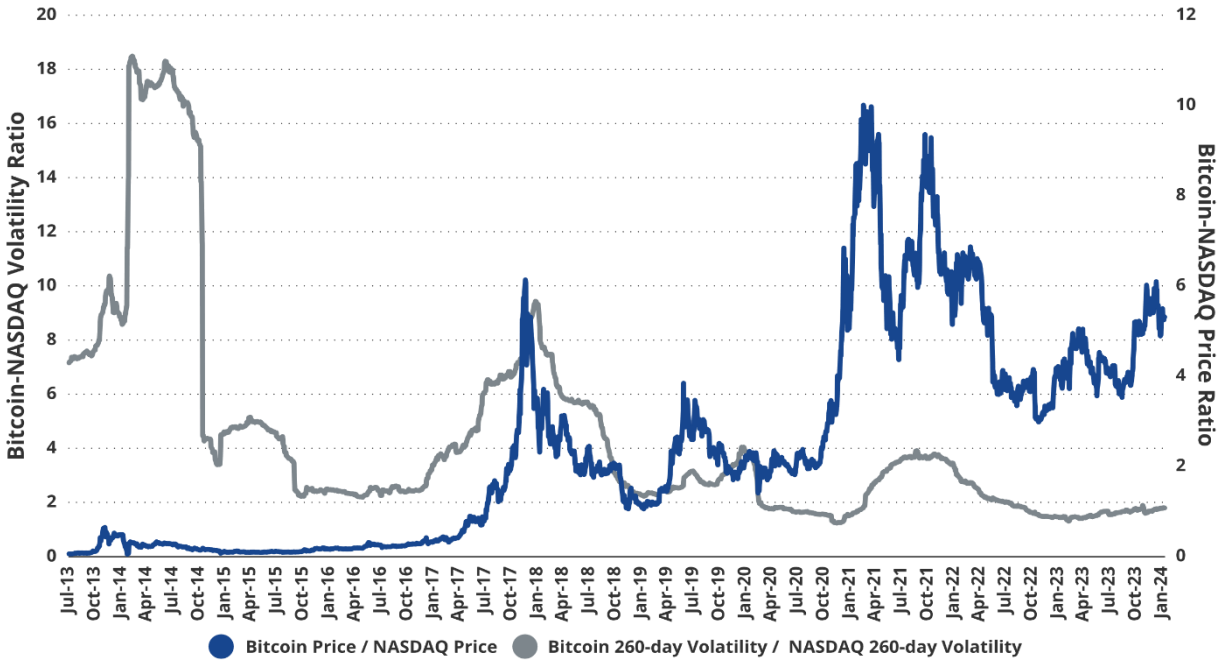

Figure 2: Bitcoin - NASDAQ Volatility Ratio

As of now, no such datasets exist for cryptocurrency as further study of various aspects and variables are required to predict a relatively nearby outcome. There is an importance of twenty-two drivers for the volatility of Bitcoin.[11]According to the National Bureau of Economic Research, one-third of all Bitcoins were held by the top 10,000 investors at the end of 2020. The number held by institutions and

large investors will likely keep rising as long as belief in the cryptocurrency's staying power and profitability remains strong[12]. These investors also contribute to the volatility of bitcoin. How Bitcoin whales, or investors who own substantial amounts of BTC and can affect its market value, would convert their holdings into fiat money without influencing the price of Bitcoin is unknown. Thus, the decision to be bullish or bearish with bitcoin by these ten-thousand investors(roughly 0.009% of the total global ownership) is capable of heavily impacting global economy[13].

2.3 Energy Consumption due to Mining of Cryptocurrencies

Mining basically entails confirming blockchain transaction blocks. Verification is carried out by computers that work through logical problems in search of a "nonce"—a number. Preferably, this procedure calls for "hashing" or processing power; the gain from this verification process could be more cryptocurrency.

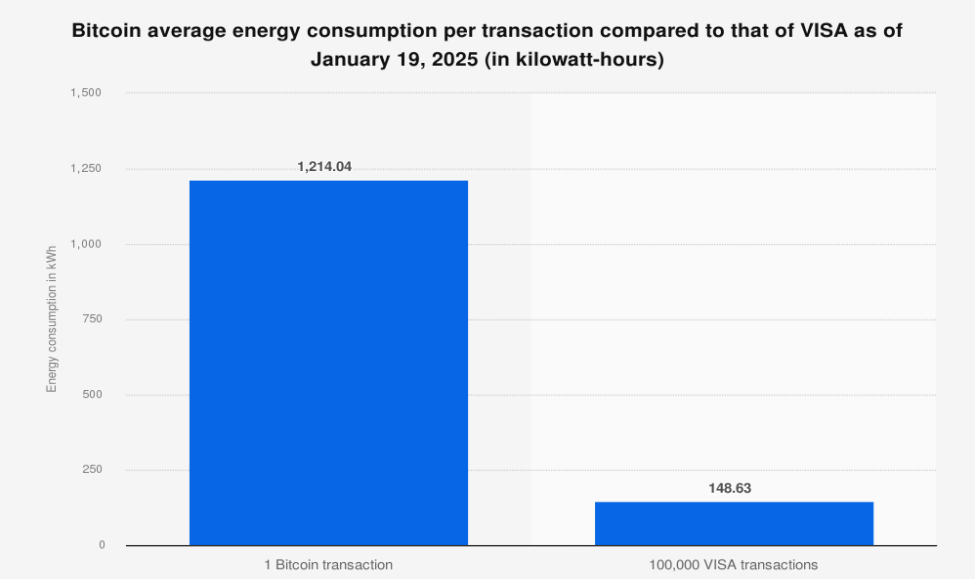

Figure 3: Energy Consumption due to Bitcoin[15]

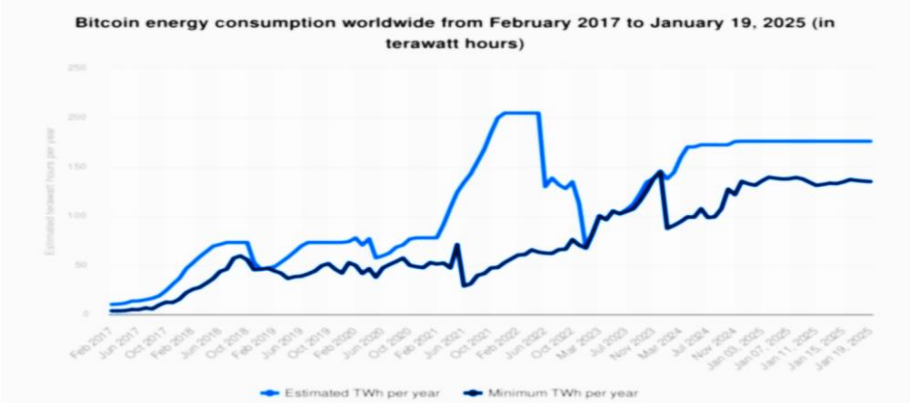

Figure 4: Cryptocurrency Energy Index (2017-2025)

According to IP addresses from people that used particular Bitcoin mining pools - or platforms that work together to mine cryptocurrencies - in 2020, the countries that mine the most Bitcoin are closely related to cheap energy prices. The cheapest electricity in the world, for instance, was three cents per kWh, while the cost of electricity in German was nearly 13 times higher[14]. **Mining Bitcoin in some European countries like the UK or Germany costs 5 times more than the Bitcoin is worth. 8 out of 49 countries where Bitcoin mining is profitable have banned cryptocurrencies**[15]. A significant amount of energy is needed to mine one Bitcoin (BTC) as an individual miner. It typically takes about 6,400,000 kWh of electricity to mine one Bitcoin. Using about 44,444 kWh of power per month, this task could take almost 12 years to complete if a lone miner were to attempt it. **The electricity needed to mine 1 Bitcoin could power 61 U.S. homes for a whole year.**[15]

3. Literature Review

Till date, the most relevant research done on the subject of the sustainability of cryptocurrencies by Yevhen Bublyk et al. has come to the conclusion that the current "proof-of-work" model, on which Bitcoin runs right now is set to reach 142 tWh of electrical energy by the year 2026[16]. It does this by analysing a co-relational regression model, using the database from the Worldwide Digital Transformation Spending Guide conducted by the International Data Corporation (IDC).

Andrae A. have concluded in their research that the demand for bitcoins - as long as it lasts - will therefore increase the demand for electric power.[17]

Anandhbalaji et al. concludes that bitcoin's yearly consumption exceeds 121 terawatt hours, equivalent to the total energy consumption of technology giants like Google, Apple, Facebook, and Microsoft combined[18].

Kohli et al. clearly puts the statement that the electrical energy consumption of cryptocurrencies is over-proportionate compared to their technical performance[19].It has been predicted that Bitcoin alone can raise global temperatures by 2 °C within the next three decades. Moreover, the concept of "Proof of Work" will lead to halving of the reward system, further decreasing the efficiency of cryptocurrency.

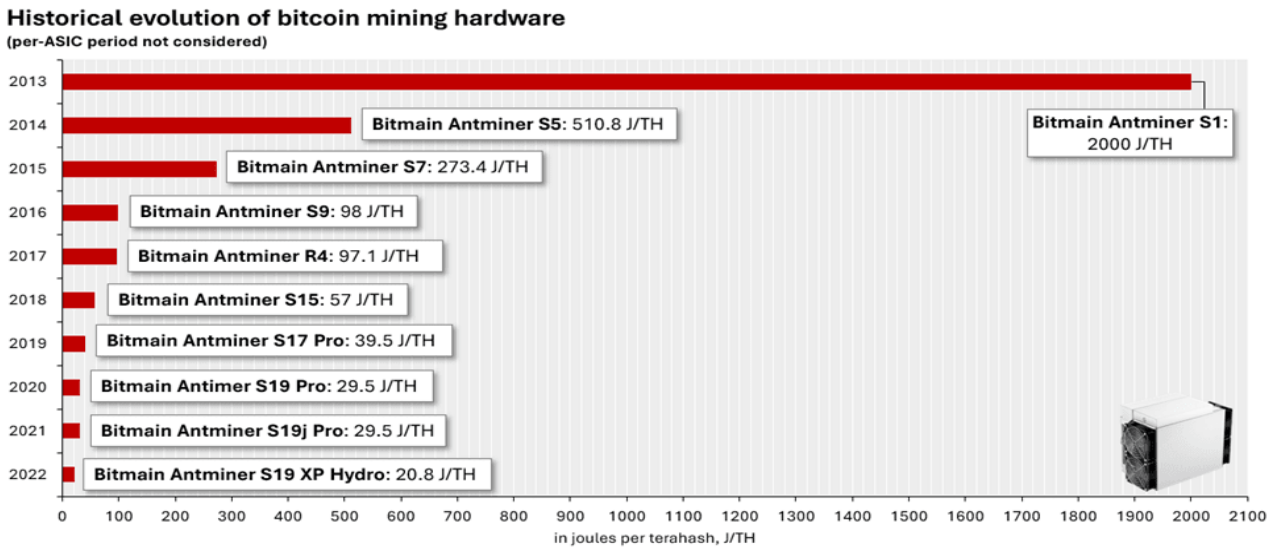

Figure 5: Source - Bitmain

According to Jingming L. et al. in 2018, Monero mining may consume 645.62 GWh of electricity in the world after its hard fork. The Monero mining in China may consume 30.34 GWh and contribute a carbon emission of 19.12 ~ 19.42 thousand tons from April to December in 2018[20].

Neumueller et al. discusses about the power usage of modern-day ASICs (application specific integrated circuits). ASICs are specialized devices which are designed to perform the specific task of hash-hunting. The BitmainAntminer S19 XP Hydro is the current flagship of the ASIC industry, delivering a staggering 260 TH/s. However, the consequent energy consumption of this ASIC is around 20.8J/TH – which means that it alone consumes 5408 J of energy per second[21].

The obvious concept according to this research is that the increase in hashing makes it harder to mine bitcoins and requires miners to contribute more computation power to maintain the same level of reward. This directly affects the profitability of mining operations.

Rafiqul et al. states that Bitcoin mining needs 17MJ (megajoules) of power to generate an equivalent $1 amount of bitcoin whereas gold mining takes 5MJ to produce an equivalent $1 amount of gold. On the other hand, there is a huge impact on the environment due to excessive use of electricity for mining bitcoin which releases more carbon dioxide (CO2) into nature[22].

Current available researches have vigorously calculated and evaluated data. However, there is a void in terms of analysis of the data with the aim to predict the survivability of cryptocurrency as a replacement to fiat currency – in terms of tangibility not in terms of the economic sector, but in the sustainability sector.

Year	Electricity used by Bitcoin mining (TWh)	Electricity usegrowth (%)	No of Bitcoin mined (x 1000)	Per Bitcoin electricity consumption (KWh)	Avg. retail electricity cost/KWh in USA (USD)	Per Bitcoin mining cost (USD)
2017	36.68		700	52,400	0.1048	5,492
2018	45.81	24.89	680	67,367	0.1053	7,094
2019	73.12	59.62	680	107,529	0.1054	11,334
2020	77.78	6.37	460	114,382	0.1059	12,113
2021	177.43	128.12	330	537,667	0.1118	60,111
Total	410.82		2830			

Table 3: Energy Consumption Statistics of Bitcoin. Source - Rafiqul et al.

4. Materials & Methods

4.1 Research Design

The aim of the research paper is to estimate the survivability of cryptocurrency with regard to its environmental sustainability, rather than economic tangibility. Hence, it involves analytical research of

factors like energy consumption, hashrate, electricity prices, mining difficulty and investment-return ratio in cryptocurrency. Though these variables are quantitative in nature, the purpose of this study is to derive a comprehendible analysis from this data with regard to other technological advancements in the world. Hence, this study is qualitative in nature.

The data has been collected from financial indexes like the Bitcoin Energy Consumption Index[23], the Bitcoin Energy Consumption[24], the European Parliament Research Service[25], and the Cambridge Blockchain Sustainability Index (CBECI)[26]. Thus, the research is secondary due to data collection approach.

4.2 Population and Sampling

The population of the study is primarily Bitcoin, due to itsPoW (Proof of Work) approach which uses energy in order to publish new block[27]. Moreover, the present research aims to analyse the survivability of cryptocurrency in place of fiat currency, and Bitcoin is currently the most used, and the oldest of all cryptocurrencies[28]. Thus, it is going to be the most probable object to base the study upon.

Hence, from over 300 cryptocurrencies to choose from, the sample is linked to the available data and previous research on energy consumption. The data available ranges from 2011 to 2024[8], and projected data up till 2140[29].

5. Results and Discussion

It is a key takeaway that Bitcoin's energy consumption is a key issue, which has been the very essence of this research. Bitcoin alone expends 91 -150 TWh of electricity annually[30]. It has also been obtained that the mining activity of Bitcoin is directly proportional to the electricity prices in the region. For example, in the USA it requires miners to incur a 50% loss per transaction while mining bitcoin, owing to the relative energy prices.

As of now, around 19.9 million bitcoins have been mined- around 94.5% of the total bitcoin supply. According to a report by CCN, on average 450 bitcoins are mined every day. With each passing day, the remaining supply diminishes, contributing to Bitcoin's scarcity and increasing Bitcoin's value proposition as a deflationary asset[31]. However, though bitcoin might hedge against inflation, the cost of acquiring bitcoin is soon going to surpass its projected growth, like it has already happened in leading economies of the world.

By 2033, more than 99% of all available bitcoin will be mined.

Though there is no single definitive figure, but COFER (Council of Forex Reserves) estimates that there is currently around 8.28trillion USD[32][33]. Hence, to imagine bitcoin as a global currency, even if we expect it to acquire a substantial 10% of this chunk, the total resulting value of bitcoin would be 800 billion USD – which amounts to roughly 40,000 USD per bitcoin. The current value of BTC is more than twice of that, somewhere around the 100-thousand-dollar mark.

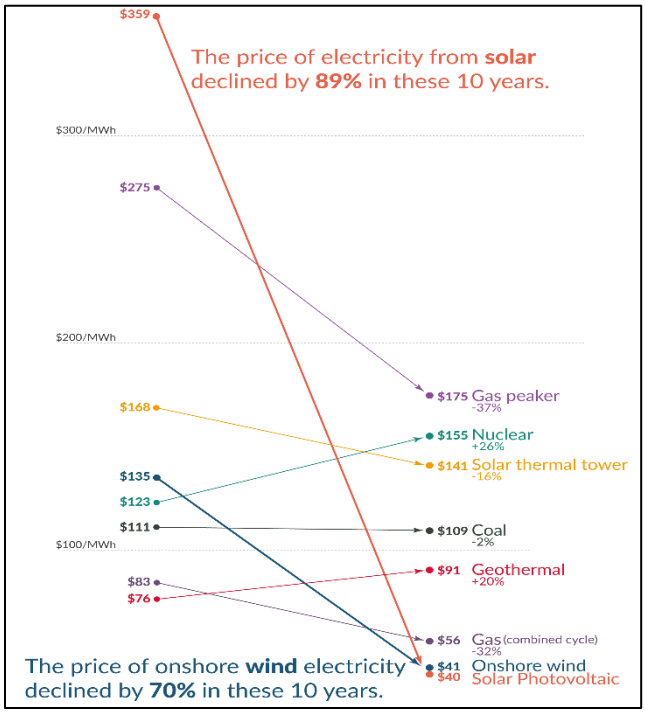

Figure 6: Projected energy

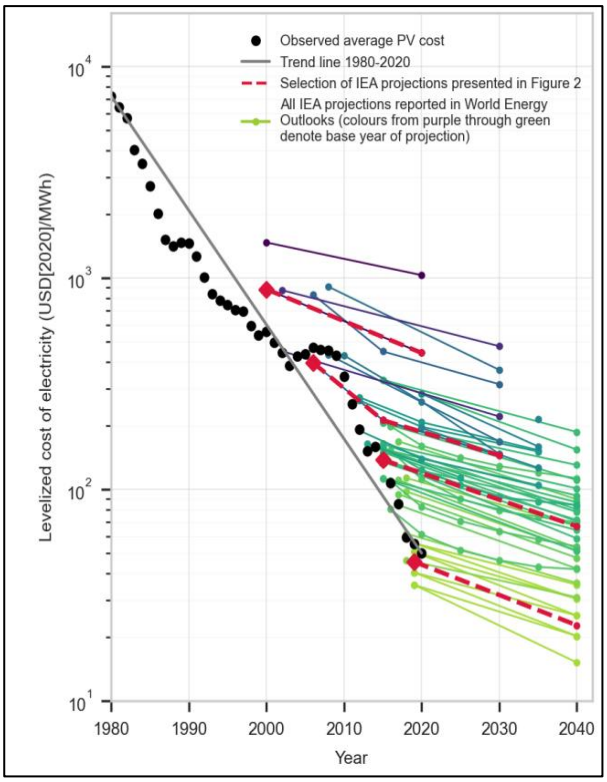

Figure 7: Drops and expected drops in

Thus, this means that the value of Bitcoin is already inflated enough as can be. Moreover, what will impact Bitcoin more is the decline in the energy prices projected in the near future[34]. The world is expected to move completely to sustainable sources of energy by 2050. Around 80% of total energy production would be an outcome of sustainable sources by 2030[35].Bitcoin runs on a proof-of-work technology, and due to the fall in energy prices, soon enough there will be no actual cost associated to the currency. With sustainable energy completely taking over by 2050[36], and electricity prices collapsing by a projected 80%[37][38], the cost of dynamic resources for the mining of BTC will prove to be negligible. The only resource to invest would be the time and hashrate of the mining equipment. This will lead to a surge in bitcoin mining, dropping its market prices and hence rendering without any actual value.

Apart from this, around 56.4 billion dollars' worth of bitcoin are in circulation today. To scale these numbers up to the projected 800 billion dollars, it would likely consume 7000 TWh of energy[39]. To put that to scale, we only produce about 8000 TWh of energy per annum[40]. The investment of about 88% of total energy produced in the world would be required to achieve this feat – which is both practically and hypothetically impossible.

6. Conclusion

Cryptocurrency can be seen as an intelligent and vital investment opportunity. However, the possibility of bitcoin, or any other proof-of-work based cryptocurrency emerging as a carrier of transactions worldwide is minimal. The world does not have enough of the electrical energy required to sustain cryptocurrency, and if the amount of energy produced increases due to a global switch to cryptocurrency, Bitcoin and essentially all proof-of-work technologies will be rendered without any actual value.

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