“AN ANALYSIS OF CRYPTO ASSETS AND FINTECH SUSTAINABILITY”

A Thesis

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Abstract

Crypto assets are a digital form of money that are programmed using Blockchain technology. The meteoric rise in popularity and usage of crypto assets and adoption of Fintech has sparked environmental concerns about its sustainability and efficiency. Specifically, questions around the extreme levels of energy consumption of assets such as Bitcoin have raised major concerns. This thesis aims at analysing the evolution of bitcoin mining hardware, taking particular interest in the performance of hardware before questions were raised about energy consumption and efficiency and the response since then. Equally, I also analyse major bitcoin mining company Enegix and Kazakhstan, one of the leading countries in bitcoin hashing rates. Results show that Bitcoin mining hardware has shown vast improvement in its efficiency over the past 10 years but there have been major increases in the cost of the hardware and annual electricity consumption. When reviewing Enegix and Kazakhstan, we can see there is major energy output. So much so that it has placed a major strain on the nations electric grid. Finally, following the review of Bitcoin mining hardware, Enegix and Kazakhstan, we take a brief look at steps Bitcoin has taken to improve its sustainability. This will ultimately help us gain a better understanding of whether contributions are being made to the improvement of sustainability and efficiency of an economy.

Abstract (Spanish)

Los criptoactivos son una forma digital de dinero que se programa utilizando la tecnología Blockchain. El meteórico aumento de la popularidad y el uso de los criptoactivos y la adopción de Fintech ha suscitado preocupaciones medioambientales sobre su sostenibilidad y eficiencia. En concreto, las cuestiones en torno a los niveles extremos de consumo de energía de activos como Bitcoin han suscitado grandes preocupaciones. El objetivo de esta tesis es analizar la evolución del hardware de minería de bitcoin, prestando especial interés al rendimiento del hardware antes de que surgieran dudas sobre el consumo y la eficiencia energética y la respuesta desde entonces. Del mismo modo, también analizo la importante empresa de minería de bitcoin Enegix y Kazajstán, uno de los países líderes en tasas de hashing de bitcoin. Los resultados muestran que el hardware de minería de Bitcoin ha mejorado enormemente su eficiencia en los últimos 10 años, pero se han producido importantes aumentos en el coste del hardware y en el consumo anual de electricidad. Al revisar Enegix y Kazajstán, podemos ver que hay una gran producción de energía. Tanto es así que ha supuesto una gran carga para la red eléctrica del país. Finalmente, tras la revisión del hardware de minería de Bitcoin, Enegix y Kazajstán, echamos un breve vistazo a los pasos que Bitcoin ha dado para mejorar su sostenibilidad. En última instancia, esto nos ayudará a comprender mejor si se está contribuyendo a la mejora de la sostenibilidad y la eficiencia de una economía.

List of Abbreviations

ETH: Ethereum

ASIC: Application Specific Integrated Circuit

ICT: Information and Communications Industry

CPU: Central Processing Unit

GPU: Graphic Processing Unit

FPGA: Field Programmable Gate Arrays

CBECI: Cambridge Bitcoin Electricity Consumption Index

BECI: Bitcoin Energy Consumption Index

ETF: Exchange Traded Fund

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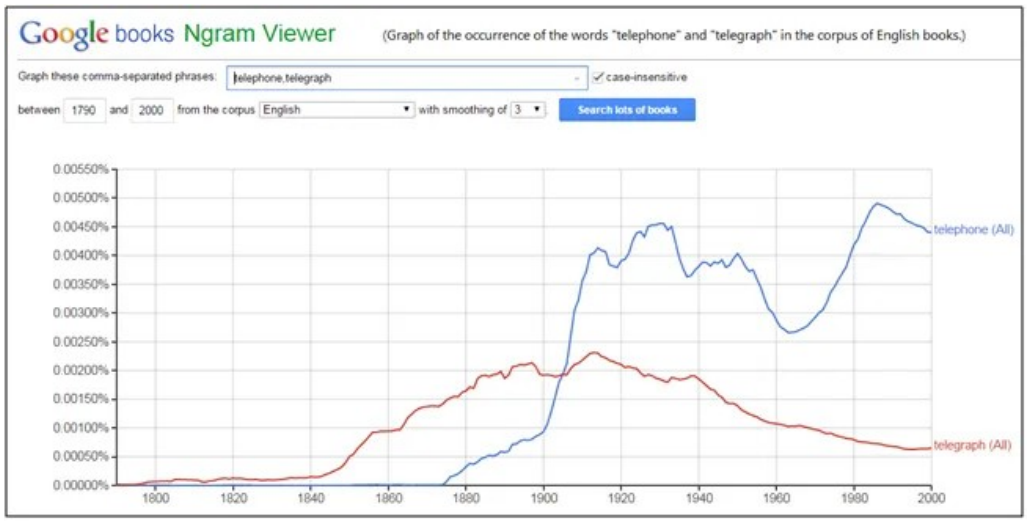
1 INDUSTRY DISRUPTORS

Back in 370 BCE, Plato worried about the introduction of writing as he feared it would weaken people's ability to memorize (Bailey, 2022)**.** A change was on the horizon regarding how we communicated and expressed our thoughts. In the late 19th century, Alexander Graham Bell made the first telephone call. The world was forever changed. A groundbreaking invention that disrupted existing paradigms and revolutionized the world of communication. An invention that many at the time believed allowed for social decentralization and increased privacy. (*1870s – 1940s: Telephone | Imagining the Internet | Elon University*, s. f.)**.**

Figure 1: N-gram Analysis to track adoption of new tech.



Fast forward to 2008, we saw the introduction of this same decentralization in the world of finance, the introduction of cryptocurrencies. The roots of cryptocurrency can be traced back to an anonymous founder known as Satoshi Nakamoto. Nakamoto published the Bitcoin whitepaper in 2008 then mined the first Bitcoin blockchain in 2009. For the first time, secure online payments could be made between two parties without the need for an intermediary such as a bank (Barstow, 2021)**.** These secure online payments were possible via the use of blockchain technology. A database that

allows for the processing and recording of crypto transactions securely. Blockchain technology allows users to carry out financial transactions without the need to provide private information. Like that of the telephone, crypto assets have shaken up the existing paradigms in the world of finance. It has spearheaded the emergence of decentralized finance. A world where traditional banking systems are being reshaped. A world without a need for intermediaries. A world where millions of unbanked adults can still send electronic remittances. Like the telephone, crypto assets have allowed for decentralization and greater privacy.

1.2 FINTECH, A SECTOR FOREVER CHANGED

Fintech, a portmanteau for Financial Technology, describes new technologies that seek to better and automate the delivery and use of financial services. Like cryptocurrencies, it has been a disruptor in the financial industry. It refers to various software, algorithms and applications on our mobiles and desktops that allow for everyday financial tasks. Tasks such as money deposits, bank transfers, paying bills and financial aid applications. Additionally, crypto exchanges are possible on Fintech platforms such as Revolut. It is reported that Fintech has a 64% global consumer adoption rate, 96% of global consumers are aware of at least one money transfer and payment Fintech service and 75% of global consumers use a money transfer and payments Fintech service (*FinTech Industry Trends in 2023*, s. f.)**.**

Fintech can be described as customer-oriented digitization. An area of Fintech that is centred around customers and their processes. The focus is financial products and services designed for hybrid, multi-purpose forms of interaction-based customer processes. A potent example of this is the electronic wallet. The electronic wallet is not only for payments, but there is also the option to collect, record and spend loyalty points and other important private data (Puschmann, 2017)

Fintech has revolutionized the way we approach investments, trade, and our everyday banking. This revolutionary effect has only been elevated by the impact of crypto assets. Fintech companies have leveraged crypto assets to create innovative solutions to problems with traditional banking systems. One being the availability of faster and more

efficient money transactions. Equally, many fintech companies have emerged that are solely focused on digital assets such as cryptocurrencies. New investment opportunities have been made available in the Fintech Industry with individuals now investing in digital assets. This has spurred on the emergence of a new asset class.

1.3 REGULATING THIS INDUSTRY

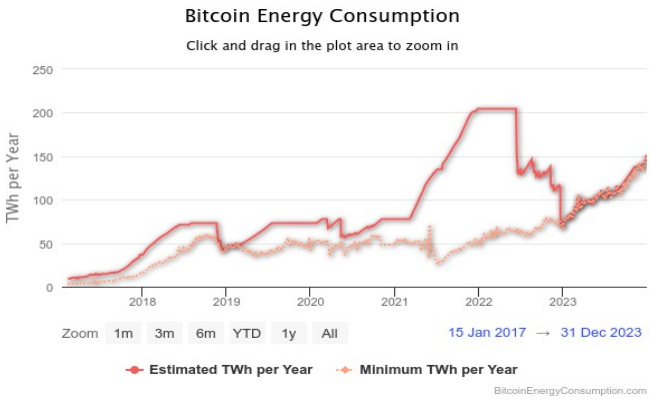
Particularly in the past 10-15 years, environmental degradation and climate change have emerged as two of the most important problems in our world today. There is a need for our economies to not only be financially viable, but also efficient. A need for environmentally friendly, green technologies. As digital currency, crypto assets and other financial assets of this type become more widely used, a seemingly 'cashless' future society, rigorous regulation of cryptocurrencies must be in place to achieve our goal of a global green economy.

The bridging of the gap between Fintech and sustainable financial activity is more than possible. Fintech tools such as blockchain and mobiles phones can work towards a greener economy (Asian Development Bank, 2018)**.** This area of fintech is what is known as Green Fintech. This aims to protect the environment and reduce poverty by providing financial access to lower class citizens at a lesser cost. This area includes artificial intelligence, big data analysis, blockchain and many more (Kabaklarlı, 2022)**.** Various green fintech companies exist today such as the peer-to-peer food sharing company in London that prevents waste of food production and greenhouse gas emissions (Makov et al., 2020)**.** In Singapore, they already have a well-established green fintech ecosystem. The Money Authority of Singapore has launched a multitude of projects to promote Green Fintech. These projects include Project Greenprint, the Singapore Green Bond Framework, ESGenome, and the Green Finance Industry Taskforce (*Fintech Can Help Advance Sustainable Development Goals*, s. f.)**.** Nations such as Indonesia and Thailand have made great strides in this regard as well. They have launched green bond markets and established financial incentives for environmentally friendly investment activity. Various initiatives have also been launched in the Arab world, specifically in North Africa and in the Middle East Region.

Saudi Arabia have made great efforts towards sustainable smart cities such as ‘The Line City’. Egypt initiated the development of the smart city know as ‘Noor City’. Along with Line City, Saudi Arabia have also launched several initiatives to spearhead the adoption of Green Fintech in the global economy. Initiatives such as the Saudi Green Initiative and the Middle East Green Initiative (Aboalsamh et al., 2023).

As stated previously, crypto assets represent Decentralized Finance. A world where millions of unbanked adults can still be a part of the global financial system. However, for years, questions have been raised regarding the sustainability of cryptocurrencies. More specifically, the mining of these cryptocurrencies, Crypto Mining. This is the process of creating new coins and validating cryptocurrency transactions on the blockchain network and adding them to a distributed ledger. The ledger is where each crypto transaction is uploaded by verified crypto miners. This secures the network and stops the problem of transaction duplication. The Bitcoin network, for example, uses mining. It is an essential activity in the Bitcoin network to validate transactions and ownership (de Vries & Stoll, 2021). Unfortunately, this process results in immense energy consumption. It is even stated that if Bitcoin usage follows the rate of adoption of other widely adopted technologies, it could produce enough carbon dioxide to increase global warming by 2 degrees over the next 30 years (Mora et al., 2018). It has been reported to have an annual energy consumption of 95.64 TWh (Terawatt Hour). An electrical power footprint comparable to the electrical energy usage of a British family over the course of two months (Digiconomist, 2022). As cryptocurrencies are traded via blockchain technology, they have very high environmental costs. For Bitcoin mining, specialized equipment and massive amounts of power are used to establish agreements on ownership and transaction details. The energy consumption of cryptocurrencies is sourced from two categories: conventional and non-conventional. Conventional sources include coal, natural gas, and oil. Non-conventional sources include solar, wind, hydro, nuclear and geo-thermal (de Vries, 2019). Most of the energy consumed by the Bitcoin mining process comes from non-conventional sources. This ultimately leads to a higher carbon footprint (Schinckus et al., 2020).

Figure 2: Bitcoin Energy Consumption 2017-2023



The crypto industry has an energy problem. In an UN Study published in October 2023, the Bitcoin mining activities of 76 nations were recorded. These findings revealed that from the period of 2020-2021, the Bitcoin mining network consumed 173.42 Terawatt hours of electricity. If Bitcoin were a country, its energy consumption would have ranked it 27th in the world ahead of nations such as Pakistan with a population of over 230 million people. Its carbon footprint is the equivalent of the burning of 84 billion pounds of coal. Equally, Bitcoin's water consumption was equivalent to filling up over 600 Olympic sized swimming pools. This is enough to satisfy the water needs of more than 300 million people in rural Sub-Saharan Africa. Additionally, the land footprint of global bitcoin mining activities was 1.4 times the size of Los Angeles. Nations such as China, The United States and Kazakhstan were leading the way in terms of Bitcoin mining from the period 2020-2021. China, by a large margin, was the biggest bitcoin mining nation. It was reported that over 2 million trees, covering area equivalent to that of Ireland or Portugal, would need to be planted to offset the carbon emissions of China's network.

1.4 OPPOSING VIEW?

Although they are many worried about the energy consumption of Bitcoin mining, Bitcoin proponents have highlighted many myths surrounding the supposed "unsustainability" of mining and have even stated it could be a strong ally in the push for renewable energy adoption and has many climate benefits. Benefits such as:

1.4.1 MITIGATION OF METHANE EMISSIONS

Methane (CH_4) is a much more potent greenhouse gas than carbon dioxide. Almost 400 million tons of methane are emitted into the atmosphere every year, largely due to human activity. An example of this is oil producers and their use or lack thereof of natural gas. Natural gas is considered economically inefficient for oil producers to utilize due to its extreme costs and lack of the adequate infrastructure. Unfortunately, because of this lack of structure, producers either vent or flare the natural gas on site leading to methane being released directly into the atmosphere. Methane is a greenhouse gas with a Global Warming potential over a 100 year period almost 40 times greater than Carbon Dioxide (Stoll et al., s. f.)**.** One kilogram of methane can heat the atmosphere by as much as 30 kilograms of carbon dioxide. The lethalness of methane cannot be understated and should be considered a top priority in the effort to combat climate change.

The most potent way to reduce methane emissions is via a process known as Reduced Flaring. This is a practice that eliminates over 90% of methane and converts it into carbon dioxide. It is considered the most efficient way to reduce methane emissions from oil extraction processes. The leftover methane from this reduced flaring process can then be transferred through generators or combustion turbines. Using combustion, the leftover methane can be turned into electrical energy. This is considered the only economically viable way to get rid of almost 100% of methane emissions (Siddique et al., 2023)**.** Bitcoin miners can place themselves near these oil fields and utilise the internal combustion to power their mining activities. A win-win scenario whereby miners can carry out their mining processes whilst simultaneously contributing to the reduction of methane emissions. This combination has the potential to substantially

reduce world emissions. It is suggested that almost 6% of global carbon dioxide emissions can be reduced by deploying bitcoin miners to these oil extraction sites that catch methane.

1.4.2 EXPANSION OF RENEWABLE ENERGY RESOURCES

As previously mentioned, Bitcoin mining has become an ally in the push for renewable energy adoption. Bitcoin miners are constantly searching for the cheapest and most efficient sources of power, and this is increasingly becoming renewable energy sources. Motivated by the need to maximise profits and reduce costs, miners are turning to solar, wind and hydroelectric power sources to power their operations. Bitcoin proponents have stated the ease and flexibility of mining. There isn't a need for mining operations to be close to urban centres or industrial parks and instead, only need to focus on locating themselves near renewable energy sources. Examples of this are:

1.4.2.1 Hydroelectric Powered Mining in Sichuan China

Sichuan Province in China has become a hub for Bitcoin mining. The region has an incredible surplus of hydroelectric power and thus serves as an ideal location for energy-intensive operations like mining. A synergy has been created and has led to the encouragement of investment in more renewable energy projects thus enhancing Sichuan's capacity to produce clean energy.

1.4.2.1 Solar Powered Mining Farms in Texas

Texas has become an important destination for Bitcoin mining due to its incredible solar energy potential. Various companies such as Layer1 have set up mining bases in West Texas as they look to capitalise on the region's vast solar resources. Additionally, bitcoin mining operator, Aspen Creek Digital Corporation began operations at a Texas Data centre. It is a 30-Megawatt centre capable of hosting 10,000 ASIC machines that are powered by the state's 87-Megawatt solar farm.

1.4.2.2 Utilization of Heat

Bitcoin proponents also argue for the utilization of heat that is generated during the mining process. There exists a potential financial incentive for miners to reutilise the heat that is wasted during mining which in turn reduces energy consumption. Suggested methods for reutilization include greenhouses, residential buildings, water systems, food and wood drying and alcohol distilleries (Stoll et al., s. f.).

1.5 HYPOTHESIS TO ACHIEVE OBJECTIVE

The objective of this study is to examine whether technological innovation, more specifically Fintech and Crypto assets, are contributing to the improvement of sustainability and efficiency in our economies.

As previously stated, climate change is at the forefront of our world's most pressing challenges. So much so that we have now made the shift from global warming to global boiling. A period in which the Earth experiences an increase in average temperatures and equally, increased occurrence and lethalness of heatwaves that threaten our ecosystems, society and global economy (Amnuaylojaroen, 2023). It

It is hypothesized that cryptocurrencies can contribute to the improvement of the sustainability and efficiency of our economies. This won't be without substantial regulatory framework development, efforts towards more sustainable power sources for crypto mining, greater impetus on Green Fintech activity and much more. We have already seen this shift towards a more sustainable process with cryptocurrencies such as Ethereum. ETH is now considered a green blockchain with low energy expenditure, however, this was not always the case. Originally it operated on a proof-of-work system before transitioning to a proof-of-stake system. Proof of work is a mechanism present in many blockchain networks used to secure and validate crypto transactions. However, this process had high environmental costs and contributed to the prior high energy consumption of Ethereum (*Ethereum Energy Consumption*, s. f.). The shift from Proof-of-work to Proof-of-stake is known as The Merge (*The Merge*, s. f.). It was the joining of the original execution layer of Ethereum with a new proof-of-stake consensus layer

known as the Beacon Chain. This process allowed for the elimination of energy-intensive mining and instead, allowed the Ethereum network to be secured using staked ETH. This meant more scalability and more sustainability.

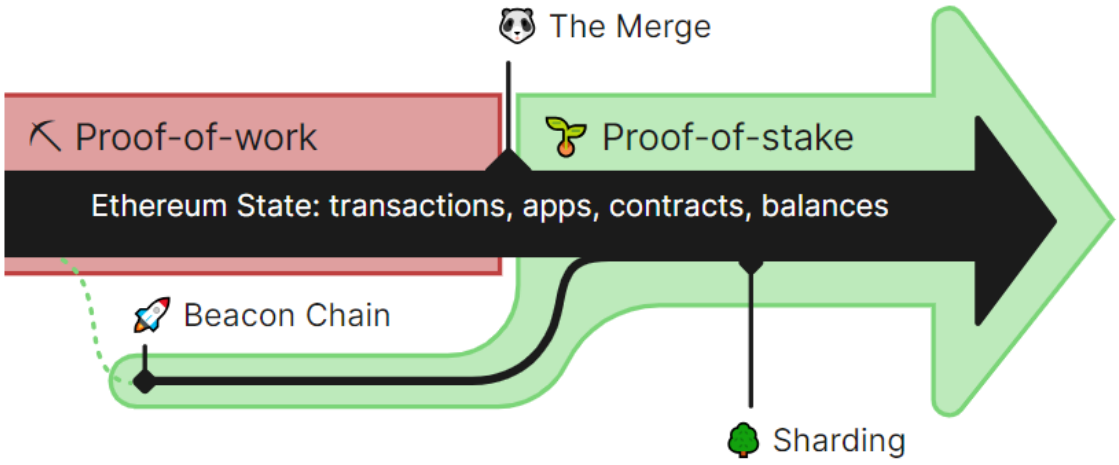


Figure 3: Visual of The Merge

Sourced: Ethereum Roadmap – Merge

1.6 BRIEF OVERVIEW OF METHODOLOGY

To adequately analyse whether Crypto assets and Fintech are contributing to the improvement of the sustainability and efficiency of our economies, quantitative data relating to sustainability and efficiency will be collected and recorded. Data such as energy consumption and efficiency of crypto assets, more specifically crypto mining. The data collected will be separated into two categories. Pre-awareness of the high carbon footprint of crypto and post awareness as governing bodies implement regulatory changes to manage this.

2 LITERATURE REVIEW

There are multitude of cryptocurrencies millions of people are trading and building portfolios with. However, for the purposes of this thesis, we will focus on Bitcoin. Bitcoin has the biggest market capitalization of all cryptocurrencies with a value of 958 billion dollars, or 888 billion euros (Ph.D, 2024).

2.1 THE BITCOIN PROCESS

As stated previously, all cryptocurrency transactions are recorded on a Blockchain. To compare it to the world of accounting, the blockchain is like a general ledger. It allows for the digital documentation of all transactions. The bitcoin is made up entirely of a blockchain network. Several transactions are recorded and stored in a block and then added to the wider blockchain network. Once added to this network, the details of each transaction cannot be altered or changed in any way. These transactions are verified and validated by miners.

2.1.1 CRYPTOGRAPHY

This transaction process uses cryptography to verify transactions, process payments and manage the supply of bitcoins. Cryptography is an essential mechanism for securing information in computer systems. Without it, cryptocurrencies like Bitcoin would be regular victims of attackers, scammers, and all sorts of fraudulent activity. It serves two main purposes which are securing transactions and verifying the transfers (Gupta et al., 2021). Cryptography is not a new phenomenon and, in fact, is implemented in a plethora of information security applications. Back to bitcoin, the coin is dependent on two cryptographic schemes: digital signatures and cryptographic hash (Badev & Chen, 2014). These two processes enable the exchange of accurate payment instructions between the parties involved and the enforcing of discipline in writing transaction records in the public ledger.

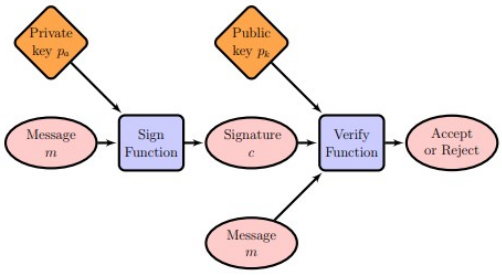


Figure 4: Cryptography key encryption process

The figure above outlines the process of digitally signing and authenticating a bitcoin transaction.

2.1.2 THE TRANSACTION

Each bitcoin resides in a bitcoin system known as a bitcoin address. The ability to send bitcoins from an address is dictated by digital signatures (shown above) via ownership of a public key and a private key. Each bitcoin address is denoted by a unique public ID which is a numeric identifier that corresponds with the public key. The private key gives control over the bitcoins held in this address. With this process, any payment involving a specific bitcoin address must be signed with the corresponding private key for the transaction to be validated.

Entities on the Bitcoin blockchain network engage in transactions through a collection of bitcoin addresses, otherwise known as their bitcoin wallet. The wallet is a set of bitcoin addresses belonging to an owner. A bitcoin transaction thus involves one or more sending addresses and one or more receiving addresses as shown in the figure below:

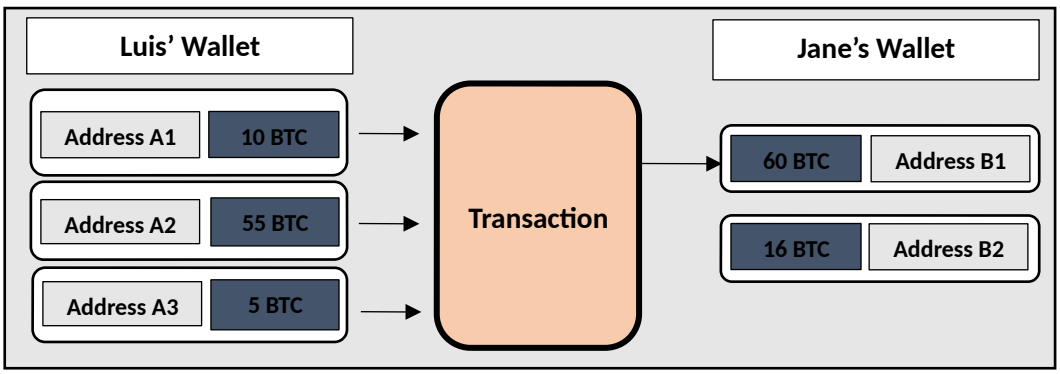


Figure 5: A Bitcoin transaction

With this process above, Luis signs the transaction message with his private key and it is communicated to the Bitcoin network. This way everyone in the network can verify that it was Luis who authorized this transaction and it has not been tampered with in any way, shape, or form. Additionally, the digital signatures in this transaction ensure that no one else could have possibly signed it.

2.2 THE MINING OF BITCOIN

As previously stated, miners verify every bitcoin transaction. This process of verification is done through consensus-based proof of work (Khairuddin & Sas, 2019). Proof of work is a blockchain mechanism that incentivizes this process of verification by rewarding miners for elevating the level of computational power and difficulty to the network. This reward is usually a certain amount of bitcoin plus any user transaction fees. The ultimate objective behind proof-of-work is to maintain the integrity and security of all transactions on the bitcoin network. This is the process behind the mining of bitcoin. A decentralized, unregulated, and lucrative practice that incentivizes miners, via the rewarding of bitcoin, for their successfully validated proof-of-work. The process whereby transactions are verified on the blockchain. This ultimately stops the possibility of double spending on the Bitcoin network where a user could spend the same bitcoin twice. Mining bitcoin can be done at home; however, one would need to invest in one of the top graphics processing units, otherwise known as GPUs, or an application specific integrated circuit (ASIC). An ASIC is an integrated circuit chip designed for a specific purpose. In this case it would be for bitcoin mining. These pieces of hardware usually cost thousands of euros. Most of the Bitcoin mining network's power is made up of ASIC mining farms and individual miners.

When new bitcoin transactions are notified to the network, the miners check the authenticity of each transaction and collect all of them into a set of transactions known as a block. Then they take the information contained in this block and run the SHA-256 hashing algorithm on this block which then turns the information into a sequence of 256-bits, known as a Hash. This is essentially a numerical identifier for a block. The

information contained in a block includes the sequence number, a timestamp, the cryptographic hash of the previous block, some metadata and a nonce, which can be changed (Kroll et al., 2013). The rest of the content contained in the block cannot be changed. The changing of the nonce allows us to create a different hash. The goal is to find a hash having a given number of leading zero bits and this number can be changed to vary the difficulty of the problem. The first miner who creates a proper hash, also known as a proof-of-work, gets the bitcoin reward. This successful hash is then stored with the block of validated transactions in the blockchain.

The process of producing a single hash can be quite easy hence why it is made more and more difficult over time to regulate the creation of new bitcoins. The proof-of-work is implemented by increasing the nonce in the block until a value is found that gives a hash with the required number of leading zero bits.

An example of a hash:
000000000019d6689c085ae165831e934ff763ae46a2a6c172b3f1b60a8ce26f

This is the block hash of the first bitcoin ever created (*7. The Blockchain - Mastering Bitcoin [Book]*, s. f.).

If the hash generated does not match the desired format, a new nonce is created and the hashing process has to start again (Nakamoto, s. f.). This process usually takes countless attempts before finding a nonce that can generate a correct hash (Cocco & Marchesi, 2016).

2.2.1 PROFITABILITY OF BITCOIN MINING

The number of bitcoins created in this manner is adjusted on a predetermined schedule in which the reward is halved each time 210,000 more blocks are made, otherwise every 4 years. The first bitcoin mining reward was 50 bitcoins per block until it was halved to 25 bitcoins in November 2012 (Kroll et al., 2013). The profitability of Bitcoin mining is not a guarantee. Firstly, mining does not guarantee a reward and secondly, there exists high upfront costs of equipment and electricity costs as the process of producing a single hash becomes more difficult to manage bitcoin generation. In a 2019 report from

the Congressional Research Service, one ASIC can use the same amount of electricity as five hundred thousand PlayStation 3 devices (Clark & Greenley, s. f.).

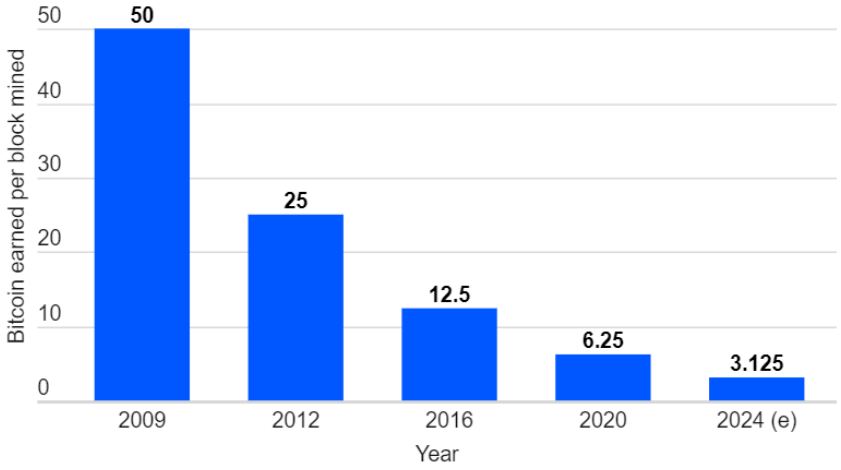


Figure 6: Reduction in Bitcoin mining payouts 2009 – 2024

Sourced: Coin Metrics Network Data

2.3 ENVIRONMENTAL IMPACT OF MINING BITCOIN

The proof-of-work system for mining bitcoin is one that has not left our environment unscathed by any stretch of the imagination. Being the most popular cryptocurrency, many have heavily scrutinized the possibility of Bitcoin being a viable alternative to traditional currency. With the concerted efforts that have been made to reduce Global Greenhouse gas emissions under the Paris Agreement, very little attention was paid to the Information and Communications Industry (ICT) as a significant player in the worsening of our environment (Belkhir & Elmeligi, 2018). Under the 2015 Paris Agreement, 196 countries agreed to the proposed plan of limiting global warming to under 2 degrees.

Since its induction, the concerns regarding the energy consumption required to mine Bitcoin have been vast. The energy intensive electronic products required for this mining process were central processing units (CPUs) and graphic processing units (GPUs) from 2009 to 2011. This evolved to Field Programmable Gate Arrays (FPGAs) up until 2013 where the ASICs took over (Bedford Taylor, 2017). The electricity

consumption of the Bitcoin network is tracked and recorded by two entities which are Cambridge Bitcoin Electricity Consumption Index (CBECI) and the Bitcoin Energy Consumption Index (BECI) which was created by Digiconomist. According to these two entities, the Bitcoin network consumed between 73.1 (*Bitcoin Energy Consumption Index*, s. f.) and 78.3 terawatt hours of electricity (*Cambridge Blockchain Network Sustainability Index*, s. f.)**.** There isn't always agreement and clarity over the annual consumption of the mining network as estimates vary based on a multitude of factors such as hardware efficiency and electricity prices used in the process (Krause & Tolaymat, 2018)**.** For example, De Vries reported that, based on an analysis of Bitcoin miner sales, it can be estimated that the network consumed 87.1 Terawatt hours of powers annually on the 30th of September 2019.

As previously mentioned, from the periods of 2021-2022, China was the leading bitcoin mining nation and substantial efforts would need to be made to offset the effects of China's mining operations. However, following China's shakedown in 2021, mining operations exploded in the United States. It is estimated that Bitcoin consumed an estimated 36-billion-kilowatt hours of electricity. This is as much as the American regions of Maine, Vermont, New Hampshire, and Rhode Island combined (*The Environmental Impacts of Cryptomining*, s. f.)**.** In 2023, it is believed that the average energy consumption of a Bitcoin transaction is the equivalent of hundreds of thousands of VISA card transactions. As previously mentioned, with each mined bitcoin and a slow approach towards it supply limit, the computational power needed to mine bitcoin becomes more and more difficult each turn. The more complex the computational process, the more energy required for this process (Ulaşan, 2022)**.**

2.3.1 TRACKING ENERGY USE AND CONSUMPTION OF BITCOIN MINING

Along with its energy consumption, understanding and identifying the exact sources of energy used in Bitcoin mining represents another significant challenge regarding this topic. The global distribution of mining operations means that a plethora of energy sources are utilized from renewable to non-renewable sources of energy. This represents

the decentralised nature of Bitcoin mining, a nod to the impact of crypto assets in decentralizing the financial industry.

The Identifying of mining facilities is particularly difficult with the lack of verification of energy sources by the miners and the likelihood of these operations to move in search of lower cost electricity. Additionally, when a mining operation is identified, information regarding its energy consumption and operational details is uncommonly unavailable or not specified to an adequate standard. The variation in facility sizes, the lack of data on said facilities and the constant change in the location and ownership all contribute to the difficulty surrounding the bitcoin mining process and identifying where the miners extract their energy (*Tracking electricity consumption from U.S. cryptocurrency mining operations - U.S. Energy Information Administration (EIA)*, s. f.).

The Cambridge Bitcoin Energy Consumption Index provides estimates of the coin's energy consumption and attempts to properly analyse its carbon intensity. However, their methods have limitations such as issues with data accuracy due the self-reporting by the miners on their energy consumption and the variation in their energy sources.

2.4. REGULATORY APPROACH FOR CRYPTOCURRENCY

All around the world, governments are exploring ways to properly regulate this new asset class that has completely revolutionized the financial world. These regulations vary from country to country with the inclusion of cryptocurrencies in new regulation for taxation, money laundering, counterterrorism, organised crime, and the drafting of regulatory frameworks to protect users whilst they engage in crypto transactions. For example, in Australia and Canada, laws were implemented to place crypto transactions and the institutions that oversee these transactions under the scope pf money laundering and counterterrorist financing laws (Law at Sogang University School of Law. J.D. (Pittsburgh) & Riley, 2021). Additionally, regarding Canada, it was the first country to approve a Bitcoin exchange traded fund, also known as an ETF, on the Toronto Stock Exchange. Canada also classifies all crypto investment firms as money service businesses and requires that they register with the Financial Transactions and Reports

Analysis Centre of Canada. Across the border in the United States, the Federal Government considers cryptocurrencies as property. With variance in regulation from state to state, certain agencies have proposed rigorous regulation for digital wallets and exchanges whilst others have taken a more lenient approach. In New York, strict disclosure and consumer protection requirements have been deployed for any businesses that offer cryptocurrency related services in the state (*Virtual Currency Businesses*, s. f.). In 2023, the Government of Spain announced that they would be bringing forward the implementation of the European regulation on the crypto assets market in Spain by December 2025. This is aimed at creating a safe and stable regulatory framework for the protection of investors in crypto asset services and legal certainty (*Spain Brings Forward the Implementation of the World"s First Crypto-Assets Market Regulation*, s. f.). Over in the United Kingdom, the lower house of the British Parliament recognized crypto assets as regulated financial instruments in October 2022 (*CRYPTO100350 - Compliance*, s. f.). Equally, cryptocurrency exchanges must comply with the reporting standards of the Office of Financial Sanctions Implementation. All firms based in crypto investment must notify the financial body as soon as possible if they aware of anyone that has committed a financial sanctions offense (cms-user20, 2024).

Amongst the influx of new regulation to manage the rapid growth of crypto, many countries have completely banned cryptocurrency use altogether. Countries such as Algeria, Bolivia, Morocco, Nepal, Pakistan, and Vietnam have banned all cryptocurrency activities. One of the more prevalent examples of this is China.

2.4.1 CRYPTO BAN IN CHINA

Of all the regulations implemented to manage the revolutionary impact of Bitcoin in the financial world, China must be the most extreme with its complete ban of all cryptocurrency transactions in late September 2021. This action was carried out by The People's Bank of China which cited the role of cryptocurrencies in aiding in financial crime and its risk to the country's financial system (*What's behind China's Cryptocurrency Ban?*, 2022). Prior to this trade, Chinese Investors were prominent

players in the Bitcoin Market with China being a leading Bitcoin mining nation from the period of 2020-2021. Equally, since 2013, the Chinese yuan grew in popularity to become the most popular fiat currency that Bitcoin was traded with.

This crackdown on cryptocurrency to its ultimate ban began in late 2017. China views digital decentralised finance as more harmful than useful to their financial ecosystem. From the perspective of Beijing, cryptocurrencies encourage outside players in the financial system in a manner that aggravates this system thus why the ban is still in place till this day. In greater detail, China's apprehensive and rigorous approach to cryptocurrencies stems primarily from capital outflows. Crypto can disguise capital outflows. This is something that Chinese officials have constantly been trying to manage (Kapron, s. f.). Equally, the involvement of cryptocurrencies in money laundering.

3 METHODOLOGY

To properly analyse whether Bitcoin can contribute to an improvement in the sustainability and efficiency of economies, I have picked timelines of analysis marked by pre and post awareness of Bitcoin's levels of energy consumption and public discourse as information about Bitcoin became more mainstream. With these timelines, we will see the evolution of efficiency in Bitcoin mining and its electrical consumption.

I will also be analysing the geographical distribution of Bitcoin Mining farms worldwide. With knowing their locations, we can gain an understanding of their energy sources, energy output and their positive or negative effects on the local economy.

3.1 EVOLUTION OF HARDWARE IN BITCOIN MINING

In the first section, we will look at the evolution of hardware used in the Bitcoin mining process from 2009 to 2020 and then post 2021. The timeline is specifically split by a pivotal moment in 2021 where Elon Musk brought light to the environment impact of Bitcoin mining thus resulting in widespread conversation. It is also marked by China's

crackdown on Bitcoin in 2021 that followed shortly after Elon's comments. From 2009 to 2012, Bitcoin mining was usually done on personal computers using CPUs and GPUs. ASICs were introduced around 2013 and this marked a major advancement in mining hardware. From 2017 to 2020, environment concerns began within the Bitcoin community but had not yet spread to the wider public. This period also saw improvements in ASIC technology. Post 2021, we will see changes and developments in the Bitcoin mining process due to the increased widespread conversation regarding it.

3.1.1 COLLECTION OF RAW DATA

For this section, I will analyse various hardware tools that are essential for the cryptography process of Bitcoin, taking particular interest in their power consumption and Hash Rate. This will ultimately help us to calculate the energy efficiency. The main goal is to see if there has been an improvement in energy efficiency of the hardware used in the bitcoin mining process from pre-awareness of Bitcoin's high energy consumption and post awareness of it. Along with Power Consumption and Hash Rate, I will also state the release year of the model and estimated annual electricity consumption. In the table below, I have stated each metric and my reason for including them:

METRIC	DESCRIPTION	REASON FOR INCLUSION
Hash Rate (TH/s)	Tracks total number of tera hashes that a miner can attempt per second	Indicates the speed at which a computer/miner is completing an operation. A higher hash rate/speed means more processing power which is essential to greater efficiency
Power Consumption (Watts)	Indicates level of electrical power consumed during the mining process by the hardware	A great indicator for level of operational costs and carbon footprint making it essential to analysing level of sustainability
Energy Efficiency (W/TH)	Indicated by watts per tera hash and calculates the necessary power to produce one tera hash	A key metric in understanding and contextualising technological advancement of mining hardware. Lower values mean more energy efficient hardware
Annual Electricity Consumption	Provides an estimated value of total energy consumed over the course of a year by a miner	Helps us gain numerical data on the environmental impact and operational costs of the hardware

Table 1: Metrics used in raw data collection.

3.1.2 DATA PROCESSING

I have chosen to measure in tera hashes as this provides a clear metric to analyse the evolution of performance of hardware in the Bitcoin mining process. Regarding scale, the difficulty of cryptography has increased tremendously since the early days of Bitcoin as previously mentioned. The use of tera hashes allows for better representation of the skill level of a Bitcoin miner and greater comparability between the various mining hardware that will be analysed. It can also be considered industry standard to measure in tera hashes. In other reports on Bitcoin mining hardware such as The Evolution of Bitcoin Hardware by Michael Bedford Taylor (Bedford Taylor, 2017) and Bitcoin's Growing Energy Problem by Alex de Vries (de Vries, 2018), we see tera hashes as the standard metric being used.

3.1.3 EFFICIENCY CALCULATION

To calculate the efficiency of the mining hardware and to estimate electricity consumption, we will use the following formulas:

Energy Efficiency

$$\frac{\text{Power Consumption (Watts)}}{\text{Hash Rate (TH/s)}}$$

The formula chosen to calculate the energy efficiency of each mining hardware measures exactly how much electrical power is needed to produce a unit of mining power. The use of W/THs also aligns with industry standards haven been used in other articles on energy efficiency of bitcoin mining hardware such as Bitcoin Mining and Its Energy Footprint by Karl J. O'Dwyer and David Malone (O'Dwyer & Malone, 2014).

Electricity Consumption

$$\frac{\text{Power Consumption (Watts)} \times 24 \times 365}{1000}$$

3.1.4 DATA ANALYSIS

The mining hardware chosen Table 2 represent the hardware that was most used by miners pre awareness of its high energy consumption and post awareness of it. With these recorded models, a true idea will be garnered regarding whether the efficiency of bitcoin mining has improved or not.

3.2 ANALYSIS OF ENEGIX BITCOIN MINING COMPANY

In this section, I will be taking a closer look at Enegix, one of the largest bitcoin mining companies in the world and Kazakhstan, the home of this mining facility. We will see if their current operations contribute to the improvement of the efficiency and sustainability of the economy of Kazakhstan and if not, are efforts being made for it to eventually be a more sustainable player for technological innovation.

In recent years, cryptocurrencies have skyrocketed in popularity amongst the population of Kazakhstan and now it is one of the leading bitcoin mining nations in the world amongst the likes of The United States and Russia. Therefore, when we are talking about the potential, or lack thereof, of crypto assets such as bitcoin contributing to the sustainability of an economy, nations such as Kazakhstan and their major bitcoin operations like Enegix must be analysed.

3.2.1 COLLECTION OF RAW DATA

Regarding gathering data on the efficiency and sustainability of Enegix's practices, I will primarily use academic articles and industry reports to gain an idea of the company's functioning and whether sustainability is even factor where possible. It will also be supported by information on Kazakhstan as a whole.

3.2.2 DATA PROCESSING

Key metrics such as the energy output of Enegix and their mining farms will be measured in megawatts. This is the standard unit of measurement when we consider the scale of operation that exists at Enegix. This is also the usual standard when measuring the energy output of other large-scale operations such as a power plant. The electric production and consumption of Kazakhstan will also be reviewed as this is closely tied with the mining practices in the country.

3.2.3 DATA ANALYSIS

In the table 4, we will see a breakdown of Enegix's operations looking at their energy output, main energy sources, their carbon footprint, economic impact and whether there are any future plans to improve the sustainability and efficiency of their operations if needed.

4 RESULTS

4.1 BITCOIN MINING HARDWARE

MODEL	RELEASE YEAR	HASH RATE (Th/s)	POWER CONSUMPTION (Watts)	EFFICIENCY (W/Ths)	ESTIMATED ANNUAL ELECTRICITY CONSUMPTION (kWh)
PRE-AWARENESS (2009-2020)					
Antminer S1	2013	0.180	360	2000	3,153.6
Antminer S7	2015	4.73	1293	273.36	11,326.68
Antminer S9	2016	11.5	1127	98	9,872.52
Antminer S19 Pro	2020	110	3250	29.54	28,470
POST-AWARENESS (2021 – NOW)					
AvalonMiner 1246	2021	90	3420	38	29,959.20
Antminer S19J Pro	2021	100	3050	30.5	26,718
Antminer S19 XP	2021	140	3010	22	26,367.6
Bitmain Antminer S19 XP Hyd.	2022	255	5304	20.8	46,463.04
MicroBT Whatsminer M50S	2023	126	3276	25.6	28,697.76

Table 2: Bitcoin Mining Hardware and their Efficiency Rates

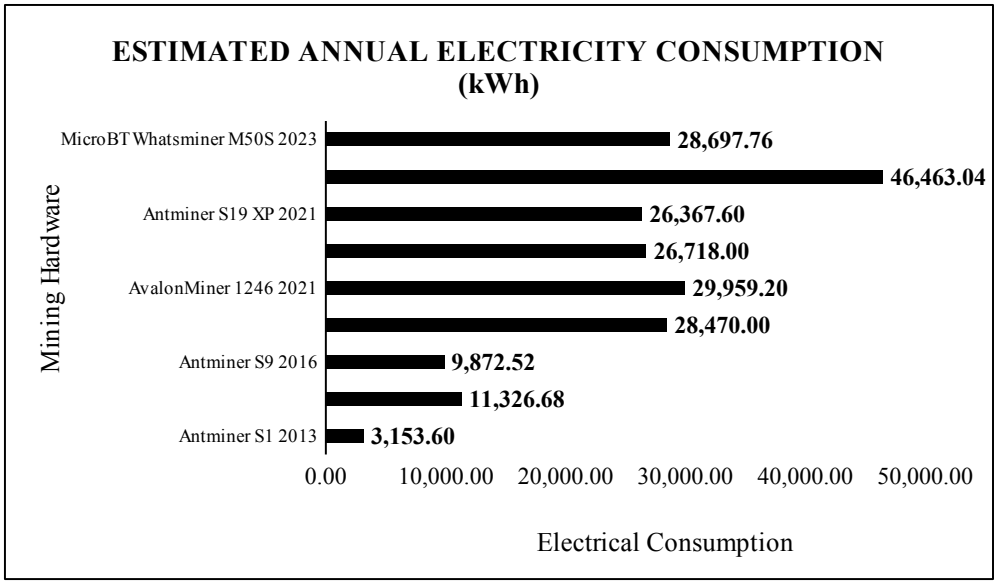


Figure 7: Evolution of Annual Electricity Consumption 2015-2023

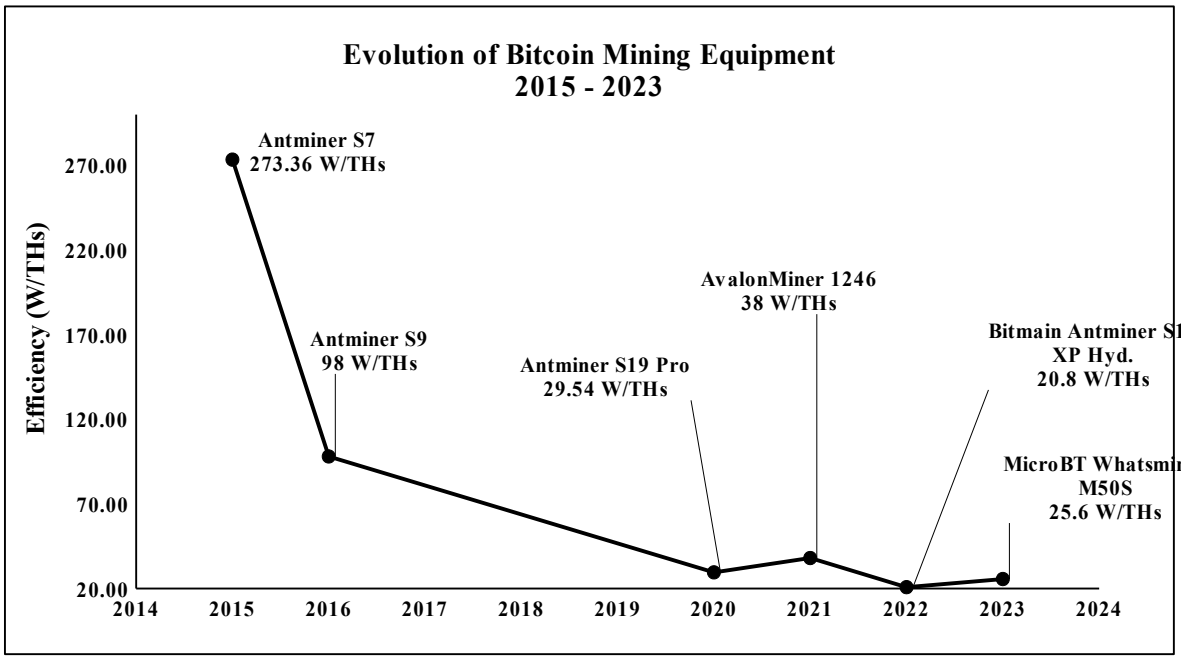


Figure 8: Evolution of Bitcoin Mining Equipment 2014-2023

NOTE: With Efficiency, the lower the better

MODEL	RELEASE YEAR	CURRENT PRICE (In dollars)	EFFICIENCY (W/THs)
PRE-AWARENESS (2009-2020)			
Antminer S1	2013	200	2000
Antminer S7	2015	700	273.36
Antminer S9	2016	319-389	98
Antminer S19 Pro	2020	1,849	29.54
POST-AWARENESS (2021 – NOW)			
AvalonMiner 1246	2021	1,349	38
Antminer S19J Pro	2021	2,000-2,100	30.5
Antminer S19 XP	2021	2,649	22
Bitmain Antminer S19 XP Hyd.	2022	6,399	20.8
MicroBT Whatsminer M50S	2023	2,249	25.6

Table 3: Bitcoin Mining Hardware, their Efficiency Rates and Prices

Prices obtained from following site: https://www.cryptominerbros.com/

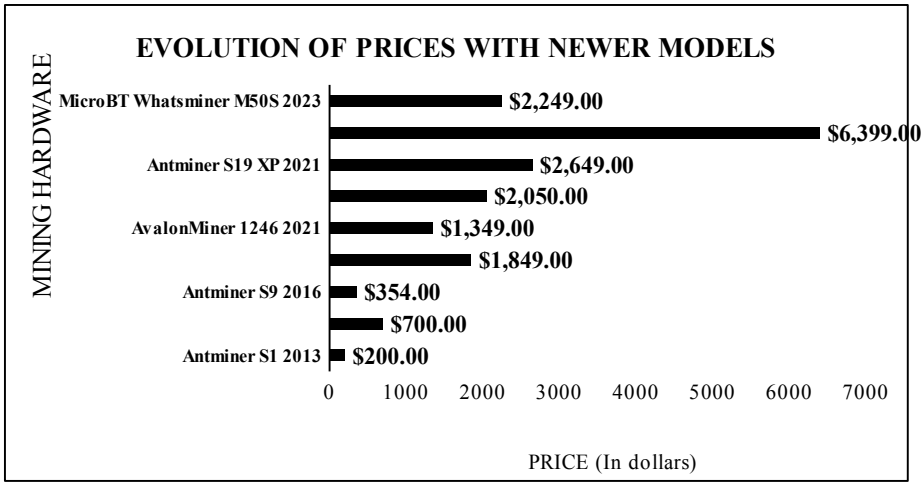


Figure 9: Evolution of Bitcoin Mining Hardware Prices

In Table 2, we have arguably the most prominent Bitcoin mining hardware of each year accompanied by their Hash Rate, Power Consumption, Efficiency and Estimated Annual Electricity Consumption. As we can see, there was vast improvement in the level of efficiency of these hardware models. The first model, the Antminer S1 had an efficiency of 2000 W/Ths. This can be attributed to its very poor hashing rate of 0.180 TH/s. This is represented the very slow processing speed and the rate at which miners could complete a hash back in the earlier days of Bitcoin. However, as the years go by, as we see in Figure 7 with the Evolution of Bitcoin Mining Equipment, there was a drastic improvement in the level of efficiency. From the Antminer S1 with an efficiency of 2000 W/Ths to the Bitmain Antminer S19 XP Hyd, released in 2022, which had an efficiency of 20.8. Bitcoin mining hardware is much more capable today with hashing rates such as 255 TH/s and 126 TH/s now being the standard.

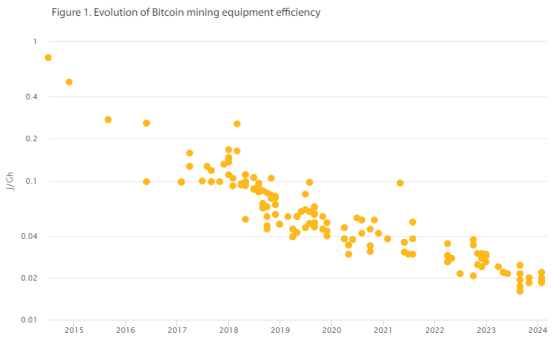


Figure 10: Evolution of Bitcoin Mining equipment efficiency

Source: Cambridge Bitcoin Electricity Consumption Index

Along with our findings that highlight an improvement in the efficiency of mining hardware, we have a scatter graph from the Cambridge Bitcoin Electricity Consumption Index above to validate our findings. The efficiency was calculated in Joules per Gigahash (J/Gh) and a lower J/Gh ratio indicates more efficient mining. As we can see, efficiency has improved immensely.

With the improvement in efficiency, also comes an increase in the Estimated Annual Electricity Consumption. Beginning with the Antminer S1 or even the Antminer S7, we had electric consumptions of 3,153.6 kwh and 11,326.68 kwh respectfully. Fast forward now to more recent models such as the MicroBT Whatsminer M50S, we have electrical outputs of 28,697.76 kwh.

We also see an increase in the prices of the mining hardware. The more efficient the piece of hardware, the more costly the hardware is. We can see this with the Bitmain Antminer S19 XP Hyd which has the greatest efficiency of 20.8 amongst the hardware models in our table whilst being the most expensive with a current price of 6,399 dollars.

4.2 ENEGIX KAZAKHSTAN MINING FACILITY OPERATIONS

CATEGORY	DETAILS
Location	Ekibastuz, Kazakhstan
Energy Capacity	180 Megawatts
Hosting Capacity	50,000 Bitcoin Mining Rigs
Energy Sources	Coal
Carbon Footprint	Likely significant footprint due to heavy reliance on coal to fuel operations at mining farms
Economic Impact	Following its opening in September 2020, between the end of 2020 and the first nine months of 2021, there was a surge in the GDP (3.0 Points) of the services sector (Bitcoin mining based in this sector) Although it may not necessarily be causal, it coincides with the arrival of new mining farms in Kazakhstan following crackdown in China.
Technological Advancements	Utilizes high quality ASIC technology to mine hardware such as the Antminer S19 Pro and MicroBT Whatsminer
Future Plans	Expansion of energy capacity to 500 MW. Aimed for 2025

Table 4: Key Information regarding Enegix major mining facility in Kazakhstan.

ELECTRICITY (Measured in kWh)	2023	2024	2025	2026
Production	120.9	123.5	128.1	128.5
Consumption	114.5	118.0	120.8	124.1

Table 5: Past and Projected Electricity Production and Consumption in Kazakhstan 2023-2026 according to Ministry of Energy of the Republic of Kazakhstan

Source: Ministry of Energy of the Republic of Kazakhstan, 2024

ELECTRICITY (Measured in kWh)	2024	2025	2026	2027	2028	2029
Production	123.27	127.66	134.99	138.97	140.5	140.53
Consumption	124.84	129.25	133.63	137.28	141.78	146.01

Table 6: Past and Projected Electricity Production and Consumption in Kazakhstan 2024-2029 according to Ministry of Energy of the Republic of Kazakhstan

Source: Data sourced from academic paper Risk Analysis of Cryptocurrency in Kazakhstan by Sabit et al., 2023

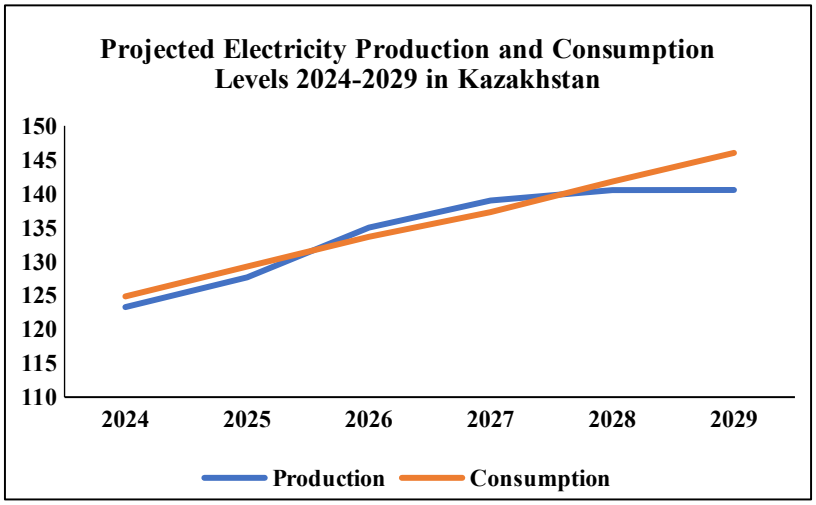


Figure 11: Projected Electricity Production and Consumption Levels 2024-2029 in Kazakhstan

Reviewing the information in Table 4, Enegix has a 180-Megawatt Bitcoin Mining Facility stationed in Ekibastuz, Kazakhstan. Its energy capacity makes it one of the largest scale mining operations in Kazakhstan today with enough electricity to power 180,000 US homes (Basile, 2022) It has plans to expand up to an energy capacity of 500 Megawatts by 2025. The site can host 50,000 mining rigs with the Antminer S19 Pro series and MicroBT Whatsminer series. Although I was unable to find specific data regarding the carbon footprint of Enegix, we can assume that it is significant considering the scale of operation and the fact that its main energy source is coal, a non-renewable energy source. Historically, Kazakhstan has always relied heavily on coal as their main source of energy. So much so that coal accounted for almost 70% of the country's power generation in 2022 («Opinion», 2023)**.**

In Table 5, we have the projected electricity consumption and production in Kazakhstan for the years 2024 to 2026. This information was sourced from Ministry of Energy of the Republic of Kazakhstan and is key due to the questions that have been raised regarding the strain that mining facilities such as Enegix have put on Kazakhstan's power grids. We see this importance with Table 6 where we have the projected electricity consumption and production in Kazakhstan for the years 2024 to 2029, sourced from the academic paper, Risk Analysis of Cryptocurrency in Kazakhstan. The disparity in information could be due to the year difference in when the projections were recorded. The projections from the academic paper were gathered in 2023 whilst the projections from The Ministry of Energy of the Republic of Kazakhstan that I sought after myself were from this year 2024. Figure 11 gives us a visual representation of the supposed strain on the electrical grid on Kazakhstan due to mining facilities housed there such as Enegix.

5 DISCUSSION

In my methodology section, I firstly reviewed the evolution of bitcoin mining hardware. I paid particular interest in whether there was an improvement in the efficiency of the hardware from 2009 to now. As seen in table 2, there was vast improvement in efficiency going from devices such as the Antminer S1 with a dismal efficiency of 2000 W/Ths to devices such as the Bitmain Antminer S19 XP Hyd and the MicroBT Whatsminer M50S with efficiencies of 20.8 W/Ths and 25.6 W/Ths respectfully. It displays the great strides that have been made in the bitcoin space having hardware that can perform a much higher number of calculations per unit of energy consumed. This is particularly important as the process of producing a single hash becomes more and more difficult to manage bitcoin generation. However, as seen in Table 3 and Figure 9, the improved efficiency has come with a sharp increase in the price of the hardware and the estimated amount of electricity consumed in a year. As the Bitcoin space has exploded, large-scale operations like the Enegix 180 MW mining facility in Kazakhstan have risen to capitalise on the profit potential that exists in the crypto space.

Figure 12: Global Bitcoin Network Hash Rate 2020-2024

Source: Hash rate Index

The global hash rate of Bitcoin has grown exponentially since its inception and even in just the last 4 years as seen in figure 12. This major increase in the global hashing rate,

where countries such as Kazakhstan lead the way, has therefore led to more energy consumption to maintain the security of the Bitcoin network and the validation of transactions. The increased energy consumption has major environmental implications such as a high carbon footprint which, as we already know, is a major problem for the Bitcoin network. This is all ties back to Bitcoin's proof-of-work system to validate transactions. A system that demands much higher computational power when compared to the proof-of-stake system that Ethereum uses. There exists within the Bitcoin system a trade-off between efficiency and consumption. Although great strides have been made with bitcoin's efficiency, it can be argued that it is being cancelled out by large-scale operations like Enegix's mining facility in Kazakhstan that are housing over 50,000 mining rigs running countless MicroBT Whatsminer M50S series machines. A piece of hardware with an estimated electrical consumption of 28,697.76 per year.

Equally, as previously mentioned, the cost of mining hardware has increased as its efficiency has increased. This creates a space where it's more likely for major corporations to make the switch to more efficient hardware and the other hand, there is a late adoption amongst everyday miners as not all may have the financial means to purchase newer hardware. Additionally, profitability can be said to be the number one goal of corporations like Enegix and thus to offset the increase in prices of more efficient hardware, they set up shop in nations such as Kazakhstan where the cost of electricity is cheaper.

We see the problems that have come with this constant search for profit with Enegix and its operations in Kazakhstan being a prime example. In tables 5 and 6, we see a disparity between the levels of electricity production and consumption in the nation of Kazakhstan. As previously stated, this may be due to the year's difference in when each projection was recorded but it also speaks to the energy problem that has birthed in Kazakhstan due to bitcoin mining facilities. Corporations such as Enegix set up shop in Ekibastuz, Kazakhstan due to its cheap electricity and abundance of coal. Its 180-Megawatt facility is reported to use power at a level that is over five times the demand of the city of Ekibastuz itself. A severe strain has been placed on the country's energy grid. This has led to power shortages that resulted in localized blackouts throughout the country (*Bitcoin Mining Was Booming in Kazakhstan. Then It Was Gone.*, s. f.)**.** This

serves as another example of Bitcoin's lack of contribution to the sustainability and efficiency of an economy, which in this case was Kazakhstan.

However, steps are being taken to make Bitcoin a more sustainable industry. Firstly, in Bitcoin halving. As mentioned previously, the reward in the network for finding a nonce is halved each time 210,000 blocks are made or every 4 years. The reward is set to be halved again this year and its impact on profitability could potentially encourage miners to seek more sustainable energy resources. The new halving is set to reduce the reward to 3.125 Bitcoins from 6.25 bitcoins. This coupled with an increasing hashing rate potentially forces a search for greater efficiency via more sustainable energy sources as the profitability of mining farms are affected (*Bitcoin Halving Will Lead to More Sustainable BTC Mining*, 2024)**.** Equally, since the start of 2024, it has been reported that over 50% of the Bitcoin network is being powered by renewable energy resources (Nag, 2024)**.** We potentially could be on the verge of a new horizon in Bitcoin and its energy consumption. A significant shift is reportedly taking place with the coin's production. It all comes down to the innate adaptability that exists with Bitcoin. An aspect that adds to its decentralised nature. Bitcoin's ability to be able to work around the clock allows it to utilize renewable energy sources such as wind or geothermal and turn it into profitable venture whereas in other cases, where we commonly are left with surpluses of these energy resources, they go to waste. Equally, Bitcoin's energy use is not bound by proximity. Most energy sources need proximity to its consumers but with bitcoin, it can harness its power source regardless of its proximity. An example of this is White Rock Management. White Rock Management is a Swiss company that has focused itself on sustainable energy use. Their data centre in Sweden relies on hydroelectric power whilst their Texas Facility has an off grid that makes use of natural gas that would otherwise be wasted elsewhere. There also exists flexibility within the mining of Bitcoin as major bitcoin mining companies such as Riot have been shown to have structured power grids that are able to absorb excess energy supply and scale back during periods of heavy demand to not place too much strain on an area's power grid. Serhiy Tron, founder of White Rock Management, even believes that the narrative around Bitcoin, and cryptocurrencies in general, is shifting. He has been quoted stating*: "Profitability has to align with ecological responsibility. We are now charting a path towards a sustainable and profitable crypto future".*

6 LIMITATIONS

- Lack of available information or resources to figure out carbon footprint of bitcoin mining companies such as Enegix.
- Lack of information regarding operations of major mining farms around the world that spearhead electric consumption of Bitcoin.

7 CONCLUSION

The purpose of this thesis was to analyse whether cryptocurrencies and Fintech were contributing to the improvement of the sustainability and efficiency of economies. To tackle this issue, I focused in on Bitcoin as it is the largest cryptocurrency in the world by market capitalization and has a played a key role in the revolutionary impact of Fintech on the world of finance.

At this moment in time, when looking at the vast improvement in Bitcoin mining hardware, we can see that it is a process that is becoming more and more efficient and is utilizing more of the energy it consumes. However, that is where the persistent problem of sustainability arises. There are many operations like Enegix's mining facility that are consuming exorbitant amounts of energy, thus resulting in a high carbon footprint. At the same time, I must consider the steps that are being taken to improve sustainability. We know this is feasible with coins such as Ethereum making a shift to proof-of-stake which is much more sustainable. We see many bitcoin miners and companies making a shift towards more sustainable sources of energies. So much so that over 50% of the Bitcoin network is now powered by renewable energy resources. Ethereum's shift to proof-of-work marked a significant landmark in sustainable blockchain technology. A potent example that more energy-efficient mechanisms are possible in the blockchain space.

It is safe to say that Bitcoin is in a period of transition. In its earlier days, it was plagued with a lack of efficiency in its mining process and still now is characterised by extreme energy consumption. However, improvements are being made and we can see there are

viable methods for bitcoin to become a more sustainable currency. Its current trajectory and potential for growth show great promise. We can point to actual tangible steps that are being taken to push Bitcoin into a new era of sustainability. Steps such as the development of Layer 2 solutions such as the Lightning Network which aim to reduce the coin's energy consumption and improve scalability by processing transactions off-chain.

If we look at the broader landscape of Fintech, we can see that it is evolving with various projects that seek to complement and elevate the role that cryptocurrencies must play. Digital financial services have become more accessible and efficient due to the progression that has been seen with blockchain technology, and decentralised financial services. This progression has led to greater financial inclusion and the championing of economic efficiency.

However, there are still various questions and uncertainties that plague Bitcoin and its long-term viability in our economies. These areas of uncertainty are most potent regarding its regulation, the technological limitations that lead to its exorbitant energy consumption and market volatility. These areas pose risk to Bitcoin's continued adoption in the financial sector. The resolution of these problems and uncertainties will require significant coordinated effort by industry stakeholders, regulatory bodies and researchers to development detailed frameworks that properly ensure the security and sustainability of Bitcoin.

Additionally, the challenge posed by the integration of Bitcoin with more traditional financial mechanisms needs to be acknowledged. Although coins like Bitcoin enhance the efficiency of these systems, the problem of volatility and its speculative nature represent significant risks to the stability and sustainability of the global financial system. A balance has to be found between the search for innovation and progress whilst also maintaining stability and regulation.

There is still a lot of work to be done but that doesn't mean we are without a multitude of opportunities to elevate Bitcoin's contribution to the improvement of the sustainability and efficiency of economies. In the coming years, there needs to be constant investment in research and development and continued effort towards the adoption of greener technologies. Synergy between the public and private sectors could

be crucial in fostering an environment for innovation and sustainable economic development.

Bitcoin and Fintech have taken significant steps in improving their economic efficiency whilst the journey towards 100% sustainability is still ongoing as with many other industries as we continue the fight against climate change. The progress that has been made thus far has shown that with the proper planning and strategy, cryptocurrencies like Bitcoin can be at the forefront of a more sustainable and efficient economy. The path forward is there and apparent and the potential for Bitcoin and Fintech is huge. To achieve this potential will necessitate substantial efforts to address any regulatory, environmental and technological concerns. A continued call for more sustainable financial activity and patience in the journey there will lead to a reaping of the many benefits of the revolutionary effect that Bitcoin and Fintech have had on the financial world and society at large.

Statement on the Use of Generative Artificial Intelligence Tools in Final Degree Projects

WARNING: The University considers ChatGPT or other similar tools to be very useful tools in academic life, although their use is always under the responsibility of the student, as the answers they provide may not be truthful. In this sense, it is NOT allowed to use them in the elaboration of the Final Degree Project to generate code because these tools are not reliable in this task. Even if the code works, there is no guarantee that it is methodologically correct, and it is highly probable that it is not.

I, Kene Obiefuna, a student of Business Administration and Management with a major in International Management at Comillas Pontifical University, hereby declare that I have used the Generative Artificial Intelligence tool ChatGPT or similar IAG coding tools only in the context of the activities described below [the student should keep only

those in which ChatGPT, or similar tools have been used and delete the rest. If none have been used, delete all and write "I have not used any"]:

1. **Brainstorming research ideas:** Used to brainstorm and outline possible areas of research.
2. **Critique:** To find counterarguments to a specific thesis I intend to defend.
3. **Referencing:** Used in conjunction with other tools, such as Science, to identify preliminary references that I have then cross-checked and validated.
4. **Methodologist:** To discover methods applicable to specific research problems.

I affirm that all information and content presented in this work is the product of my individual research and effort, except where otherwise stated and credit has been given (I have included appropriate references in the TFG and have made explicit that ChatGPT or other similar tools have been used). I am aware of the academic and ethical implications of submitting non-original work and accept the consequences of any violation of this statement.

Date: 5th June 2024

Signature: Kene Obiefuna

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