MASTER THESIS

Comparative study on the environmental, political, social effects and long-term sustainability of Bitcoin, Ethereum, Tether and Cardano cryptocurrencies

from

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Abstract

The focus of the research is a comparison between the old and the new ways financial transactions are conducted all around the world regarding their sustainability performance. A lot of discussions have been going on around cryptocurrencies and if they are a product of the future or simply a trend that will slowly fade away. Less is being discussed about the usefulness of blockchain technology as it is being adopted increasingly by private and public institutions. Despite the rapid technological progression on the field, the environmental concerns regarding are on the rise with the scientific world turn their attention towards the long-term impacts. This thesis primarily aims at contributing to this field by comparing four of the largest cryptocurrencies (Bitcoin, Ethereum, Cardano, Tether) in terms of environmental social and political effects and explain their underlying technology. A secondary goal is to provide people with little to no knowledge of blockchain technology with a basic understanding and the core concepts and increase awareness of their effects. The background of the blockchain and each of the cryptocurrency under examination is discussed and the results are complemented and validated through interviews with semi-structured questionnaires. Discussion with experts on the field is crucial in understanding some of the most complex terms in relation to their overall effects. The final comparison is completed by applying a holistic approach and examining the political, economic, social, technological and environmental situation. It was concluded that the environmental impact of a cryptocurrency is directly connected with the underlying mechanisms of each cryptocurrency and can vary significantly. Additionally, all the cryptocurrencies under examination are potentially sustainable as products from a newly created market and from a sociopolitical and technological standpoint but when it comes to their environmental impact concerns are raised for Bitcoin and Ethereum. This research adds to the existing literature by comparing four cryptocurrencies with a more holistic approach and connect the social and political effects with the environmental and determine if the four different approaches to blockchain technology can be sustainable.

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List of Abbreviations

TCP/IP:	Transfer Control Protocol/Internetwork Protocol
ADA:	Cardano's native token
BTC:	Bitcoin
ETH:	Ethereum
USDT:	Tether
DeFi:	Decentralized Finance
FIAT:	Government issued currencies (e.g., U.S. Dollar, Euro)
LCT:	Life cycle thinking
LCA:	Life cycle analysis
SMT:	Sustainability management theory
US:	United States (of America)
GPU:	Graphics processing unit
CPU:	Central processing unit
TWh:	Terawatt hours
EU:	European Union
Mt CO_2:	Metric Tons of Carbon Dioxide

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Chapter 1 : Introduction

This chapter provides an overview of the background of the research and expands on the problem statement and research objective. Additionally, the structure of thesis is presented.

1.1 Background

The first electronic computer ENIAC (Electronic Numerical Integrator and Computer) was constructed during World War II by the US with the primary purpose to calculate artillery firing patterns. Its creators were John Mauchly and J. Presper Eckert Jr., who together with their colleagues at the University of Pennsylvania completed their work in 1945 *(McCartney, S., 1999)*. In 1983 the TCP/IP was established which allowed communication between computers on different networks. This is considered by many the official birthday of the internet*. (Forouzan, B. A., 2002)*. It has been less than a century, but these two inventions have changed fundamentally our way of life and perception of the world. Long-distance communication became mundane, our means of entertainment have shifted towards the digital realm and our transaction systems operate through the use of computers. In 1982 David Chaum suggested a different approach to document and secure transaction certifications with the blockchain protocol. It was not until 2008 that the first conceptualization occurred with the creation of the first cryptocurrency named Bitcoin *(Nakamoto S. 2008)*. Since then, different blockchains are being adopted progressively within financial services and other sectors. At the same time, thousands of new cryptocurrencies have emerged and created a new trade, the cryptocurrency market *(ElBahrawy, A., 2017)*. These blockchain products focus on different existing issues and try to provide several solutions. For example, ETH is the main representative of DeFi. A financial system that avoids using intermediaries such as banks or brokers and provides financial instruments to the user through smart contracts. More details on these systems are presented in the literature review. Others, such as ADA, try to reduce transaction speed, provide high scalability while reducing their environmental impact *(Ore, Ø., 2017)*. Amongst these, a unique category has been created that substitutes FIAT currencies into a 1 on 1 equivalent. For example, the most prominent "stable coin" (as they are called) is the USDT. 1 US dollar is always trading for roughly 1 USDT *(Wei, W. C., 2018)*.

The blooming of this technology and the market that was created along with it, require an ever-increasing amount of hardware resources and energy consumption *(Digiconomist.com, 2021)*. The main way cryptocurrencies are being produced is through the process called *mining*[1], but other processes also exist, such as *minting*[2], and are based on different consensus mechanisms e.g., proof of work, proof of stake, proof of authority, or proof of elapsed time that will be discussed in chapters two and four. Mining requires the expenditure of resources to create new coins or tokens. In this

[1] *When referring to cryptocurrencies the term mining does not have the same meaning. In this case mining is process of producing new coins for a cryptocurrency. Practically, generate coins through the use of electric power. (Konoth, R. K. et al 2018).*

[2] *Minting does not require resources to be conducted. Itself, it is a part of the mining process, but some coins have pre-mined their supply and as a result this part of the process is already completed.*

situation, the resources are electrical power and computer hardware. Enormous BTC (and not only) farms *(Köhler, S., & Pizzol, M. 2019)* operate mainly in China and the US which use of substantial amounts of resources. An example of a BTC farm can be seen in figure 1.

Figure 1 *: A Mining Operation for Bitcoin in China. Photo by Stefen Chow*

Where environmental concerns arise, it is common that this affects the social and political landscape as well. What are the working conditions in these mining facilities? How do governments react to social pressure about the pollution cryptocurrency generation is causing? Do lawmakers consider the environmental effects when legislating about blockchain technology? These are just a few examples of the possible connections with the currencies' operations. While a large number of research has been conducted about these topics, they focus strictly on either the economical side of things or just the environmental effects of different cryptocurrencies *(Aggarwal, G., 2019)*, *(Yarovaya, L., 2020)*, *(Corbet, S., 2020)*. The gap that my research tries to fill, is to touch upon the subject with a more holistic approach and connect the social and political effects with the environmental and determine how sustainable the four different approaches to blockchain technology that will be discussed are. These aspects are presented in the problem statement which emphasize the relevance of identifying and analyzing the environmental, political, and social effects of some cryptocurrencies that are based on blockchain technology.

1.2 Problem Statement

As mentioned in the background section, Bitcoin is the biggest offender when it comes to electricity demands *(Digiconomist.com, 2021)* and since it dominates the market (value equal to more than 55% of the total cryptocurrency market as of April 1st, 2021 *(Tradingview.com, 2021)* it paints an image that blockchain technology as a whole is an environmental hazard. Although a claim partially true based on the current situation, blockchain is still at an early stage of development and the potential for more sustainable solutions is already present albeit not widely adopted yet. In the last few years, environmental concerns have become more serious and with good reasons as global warming is becoming a serious threat and has increased economic inequality. There has been a *"25% increase in population-weighted between-country inequality over the past half-century" (Diffenbaugh, N. et al. 2019, p. 1)*. The aim is to identify the best possible solution, and assuming that cryptocurrencies are here to stay, that can only happen through comparing the existing cryptocurrency applications. With this in mind and from a preliminary literature review, it is possible to identify some of the blockchain products (cryptocurrencies: BTC, ETH, USDC, ADA) that use such solutions and focus on the environmental effects and other aspects of their sustainability. The environmental and sustainability perspectives have been pointed out as areas of opportunity to further deploy those types of cryptocurrencies; hence I will analyze them from those perspectives, aiming at contributing to the existing body of scientific knowledge about them.

1.3 Research objective

This thesis aims to give a more holistic analytical approach when comparing those applications by using lifecycle thinking and sustainability management theory. The main reason these four (BTC, ETH, ADA, USDT) different cryptocurrencies are compared in this study is due to the importance and influence they have on the financial sector (*Tradingview.com, 2021)*. Additionally, they also cover a substantial portion of the technologies and applications in the crypto world. Their effects are discussed in terms of relevant aspects to society, policies, economy, and more importantly, the environment. This latter is described through the criteria of energy demands, CO_2 emissions (direct and indirect), and scarcity of raw resources. Those were discussed to give a clear answer as to which of these technologies have the most potential for long-term sustainability. Hence, the main question that arises and is researched here corresponds to: *What are the environmental, political, social effects of the four cryptocurrencies (BTC, ETH, ADA, USDT), and are they sustainable in the long term?*

1.3.1 Research Question and Sub-questions

The research revolves around the environmental, political, and social effects and long-term sustainability of four different cryptocurrencies and the technologies they use. In order to answer this main question, a logical narrative must be followed. Firstly, the mechanisms and their effects should be discussed as they are the core of every cryptocurrency. Furthermore, the process of generating of the examined cryptocurrencies should be examined for their environmental effects. These latter effects are directly connected to the type of internal mechanisms that each cryptocurrency is using. Afterwards, comes the step of addressing the

requirements for sustainability and comparing the four (BTC, ETH, USDT, ADA) cryptocurrencies. Through this, a conclusion can be reached out about the long-term sustainability of these cryptocurrencies. Finally, after the analysis and comparison, the future implications should be discussed in order to have a holistic view of the issue(s) at hand. All in all, this project aims at raising people's knowledge level about blockchain technology, cryptocurrencies and their sustainability effects. Providing access to the basics of this technology to everyone can create a drive for more in-depth research and public acknowledgment of this ecosystem.

Following this thought process, the main question and the sub questions are as followed:

Main Question:

1) What are the environmental, political, social effects of the four cryptocurrencies (BTC, ETH, ADA, USDT) and are they sustainable in the long-term?

Sub Questions:

1) In what ways do consensus mechanisms[3] affect the long-term sustainability (as described by SMT) of these cryptocurrencies (BTC, ETH, ADA, USDT)?

2) Following life cycle thinking, what are the environmental impacts of 'mining' and 'minting' of each currency (BTC, ETH, ADA, USDT)?

3) Do these products (BTC, ETH, ADA, USDT) address the key requirements for sustainability and how do they compare with each other (using the PESTLE analysis)?

1.4 Thesis structure

The first chapter is the introduction that includes brief background information, the research objective, and questions. The second chapter is focused on the literature review and the theoretical framework which provides the base on which the research is built upon. The third chapter is centered around the methodology that is being followed. In the fourth chapter, the results of the research are presented. Each sub-question is answered here, and the four cryptocurrencies (BTC, ETH, ADA, USDT) are compared. The focus is their environmental impact and long-term sustainability following the frameworks mentioned in chapter two of the research. In the fifth chapter, you can find the discussion section. This chapter also allows for a personal view on the subject. The conclusions and the recommendations will be in the sixth chapter.

[3] A consensus mechanism is a fault-tolerant mechanism that is used in blockchain systems (and computer systems in general) to achieve the necessary consensus amongst stakeholders upon a single data value.

Chapter 2 : Literature Review

This chapter includes important historical elements and a brief description of the technology behind the cryptocurrencies under examination which are vital for understanding the purpose of this research. Furthermore, a rundown of the mechanisms and environmental effects of the cryptocurrencies and their legal frameworks are discussed and provide the reasoning behind the research approach which is also described in this chapter.

2.1 What is a Blockchain?

The first mention of a blockchain-like protocol was described by cryptographer David Chaum in his essay "Computer Systems Established, Maintained, and Trusted by Mutually Suspicious Groups." *(Chaum, D. L. 1979)*. The first complete description of blockchain technology was discussed by the research scientists Stuart Haber and W. Scott *(Stornetta Haber, S., & Stornetta, W. S., 1990)*. As shown in figure 2. *Merkle trees*[4] were introduced to the design. These blocks are connected using cryptography and each block contains a *hash*[5] of the previous block, the transaction data, and a timestamp. In this way, the need for data centers is eliminated since the data are being stored separately in each step and managed by a peer-to-peer network.

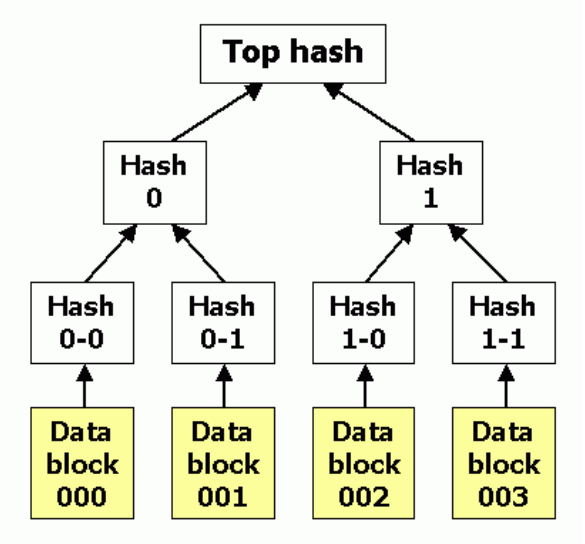


***Figure 2** : Merkle Tree Example Illustration by David Gothberg*

[4]A Merkle tree or hash tree each leaf (node) follows a branch like structure composed of "leaf nodes" which contain the cryptographic hash of a data block and "non-leaf" nodes which are labelled with the cryptographic hash of its child-nodes. This system allows secure and efficient verification in large data structures. *(Becker and Georg, 2008).*

[5] Hash is a mathematical function that through the use of cryptography allows the mapping data of arbitrary size in fixed size value. Regardless of the amount of data originally a hash will always have the same size.

2.1.1 Proof of Concept & Consensus Mechanisms

With this in mind, it is important to understand the mechanisms behind blockchain and cryptocurrencies. Proof of Concept or Proof of Principle is the actualization of a certain idea or method to test its feasibility. All consensus mechanisms fall under this description since they are fault-tolerant mechanisms that achieve the required consensus on a single data or network state *(Frankenfield J., 2021)*. In more simple terms, due to the decentralized nature of this technology a series of verifications from different participants occurs, thus reaching a consensus that is action is valid. As mentioned in the introduction many consensus mechanisms exist and implemented in the blockchain ecosystem such as proof of work, proof of stake, proof of authority, proof of burn, proof of reserves, or proof of elapsed time, and more. In this research, the focus will be proof of work that is being used by Bitcoin and Ethereum, *(Nakamoto S. 2008)*, *(Buterin V., 2013)* proof of stake that is being used by ADA, proof of reserves that is being used by Tether and proof of burn that can be used by all cryptocurrencies. More details about these mechanisms can be found in chapter four where their analysis takes place.

2.1.2 Bitcoin - The Original Cryptocurrency

A plethora of speculations exist around the early days of Bitcoin (BTC). It was created namely by Satoshi Nakamoto in 2008 but the information on this person is so limited that many consider it to simply be an alias or an international organization *(Nakamoto S. 2008), (Popper N. (2015).* That being said, the topic at hand is not to elaborate on identifying who created BTC and his/her reasons for doing that but to explain what brought it to the table of innovations. The BTC operating structure can be seen in figure 3. Each block represents a completed transaction and contains information about its past and future. For a transaction to be completed successfully and create a new block it must be verified. Therefore, each block contains the hash of the previous block, a timestamp, a version number, the hash of *Merkle root* [6], the *nonce* [7]and the target hash.

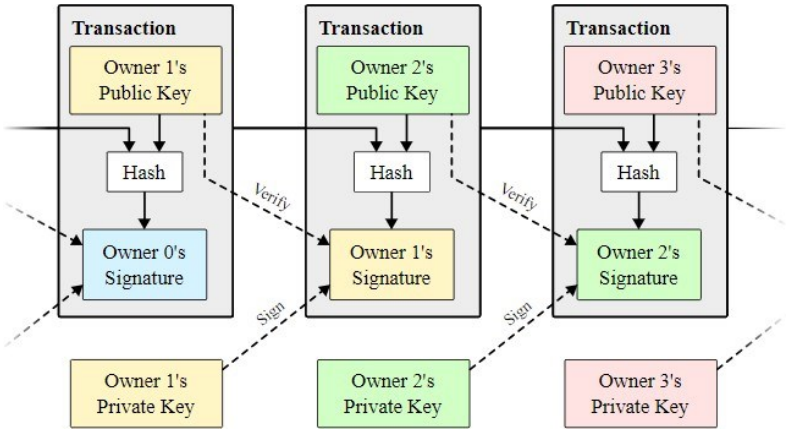


***Figure 3** : Transaction and Verification System of Bitcoin by Satoshi Nakamoto*

[6] A Merkle root is the hash that contains all the hashes of all transactions that are part of a specific blockchain.

[7] Nonce is an abbreviation of "number only used once". In the blockchain environment it is a number that is added to a block and when rehashed meets the difficulty restriction of the blockchain.

The nonce is what the crypto miners are trying to solve for each block and what creates the need for computing power. Each cryptocurrency can have a distinct set of rules as to what is allowed. For example, BTC does not have a hard limit to the coins that can be produced through mining. Instead, it has a *soft cap*[8] of around 21 million. Each subsequent coin is more difficult to mine than the previous one, thus creating the soft cap mentioned. But the increasing difficulty in the mining operations means that more and more energy is required to produce even the smallest amount of it. In addition to that, every 4 years the rewards given to the miners are halved. Some countries have invested the energy and resources of whole regions solely to this purpose as they see potential economic gains due to the rising demand for BTC completely disregarding the environmental costs *(Clohessy, T. et al, 2019).*

2.1.3 Ethereum - An Innovative Blockchain

In 2013 a group of individuals with Vitalik Buterin being the most prominent, introduced Ethereum (ETH) to the public and one year later, in 2014, became available for purchase for the first time *(Buterin V., 2013)*. In 2015 Ethereum's own network went live on 30 July. Since then, ETH has grown in popularity and succeeded in becoming the cryptocurrency with the second largest market share following only Bitcoin *(Tradingview.com, 2021)*. Where it surpasses bitcoin is in terms of uses as it is the most actively used blockchain *(Leising M., & Kharif O., 2020)*. ETH is a decentralized and open-sourced blockchain. While it validates its network transactions with the proof of work protocol it achieves a vastly different approach than BTC. The main difference is that ETH does not have a limited block size but, instead, uses *gas*[9] fees *(Antonopoulos, A. M., & Wood, G., 2018)*. Another innovation is the introduction of "smart contracts." The term was first proposed by Nick Szabo in the 1990s and it is a transaction protocol that automatically executes, controls, and documents events and actions according to the terms of a contract *(Szabo, N., 1997)*, *(Kolvart M., et al, 2016)*. Although several cryptocurrencies use smart contracts on their blockchain nowadays, Ethereum was the first one to implement them. This allowed to broaden the scope of cryptocurrencies and used for something more than simply a currency.

2.1.4 Tether – The Most Prominent Stable Coin

One more cryptocurrency with profound influence in the crypto ecosystem is Tether (USDT) which is built on the BTC blockchain. Originally named Realcoin it was co-founded by Brock Pierce, Reeve Collins, and Craig Sellars *(Tether, 2016)*, *(Casey J. M., 2014)* and it is the most used stable coin to this day with a market cap of over 62 billion US dollars *(Coinmarketcap.com, 2021)*. Stable coins are a category of cryptocurrencies with some unique properties. Their price is designed with a fixed exchange rate in mind. This price can be fixed to another cryptocurrency, FIAT money, or other valuable

[8]The term soft cap is used to describe cryptocurrencies that in theory they can produce coin indefinitely but due certain limitations (e.g., computing abilities) there is a maximum supply that can be achieved.

[9] It is a virtual fee used by Ethereum network to execute smart contracts. It is calculated by an accounting mechanism which limits the consumption of computing power and measure the consumption of gas *(Antonopoulos, A. M., & Wood, G., 2018).*

commodities such as rare metals *(Ossigen J., 2021)*. The USDT is being pegged against the US dollar 1:1 and claims that the total amount of USDT's in circulation is always backed by an equal amount of FIAT currency in their reserves *(Tether, 2016)*. The company's whitepaper explains that their system uses a process called proof of reserves to prove this claim. While stable coins are considered a solution against the volatility that exists in the crypto market *(Bullmann, D., et al, 2019)*, *(Berentsen, A., & Schär, F., 2019)* there is a number of controversies that surround USDT. Tether has been involved in several scandals with the most prominent one involving *Bitfinex*, a crypto exchange company *(Vigna P., 2019)*, and methodically refused to be audited which raised questions on the ability of the company to prove that their cryptocurrency is back by FIAT money at any given moment. Recently, if someone visited their official website *(tether.to)* they can see that the backing system has changed and now includes not only FIAT money but other assets and even loans.

2.1.5 Cardano Network – A New Approach

The last cryptocurrency here described is Cardano's native token ADA. Cardano is a decentralized and open source blockchain platform. It was founded in 2015 by Charles Hoskison who was also one of the co-founders of Ethereum *(Hoskison C., 2017)*. Naturally, a rivalry was born between the two blockchains. The two projects have many differences with the most notable being the different focus and the different consensus mechanism. While ETH is more focused on the private sector and uses proof of work Cardano is targets collaboration with public institutions and governments and uses proof of stake *(Kiayias A., et al, 2017)* which was mentioned in section 2.1.1 and requires low amounts of energy to operate. A more throughout analysis of the consensus mechanisms is found in chapter four. ADA has the lowest market dominance out of the four cryptocurrencies with only 3.05% as of 28 July 2021 *(Tradingview.com, 2021)* but its network has achieved some notable collaborations with the Ministries of Education of Georgia *(Forbes, 2019)* and Ethiopia *(Sorkin, R. A., et al, 2021)* which help legitimize cryptocurrencies. The network aims to implement smart contracts by the end of the summer of 2021 *(Kolvart M., et al, 2016)*. It is interesting to see that two large competitors in the crypto world try to implement ideas and protocols from each other. Ethereum transition to proof of work and Cardano's implementation of smart contracts drives both ecosystems on a combination of POS plus smart contracts.

2.2 Global Warming and Cryptocurrencies

Cryptocurrencies are mostly appraised through their economic value whilst their negative effects on the environment are more than noticeable *(Corbet, S., & Yarovaya, L., 2020)*. Ignoring such issues can worsen the planet's condition. Global warming is used to describe the effects of human actions especially the usage of fossil fuels and the emissions of greenhouse gasses in the atmosphere *(Houghton, J., 2005)*. Such actions lead to the rise of the global average temperature and cryptocurrencies are partially responsible for this *(Digiconomist.com, 2021)*. With global warming effects starting to become more and more extreme, it is necessary to reduce emissions and energy consumption in any way possible. The Paris agreement, although a major step towards sustainability, does not have any resolutions regarding cryptocurrencies *(Rogelj, J., et al, 2016)*. This is not neglected on the side of the agreement itself but due to the lack of

regulations, legal presence, and a more general lack of understanding of blockchain technology. On the other hand, regulations go against one of the main flagships of blockchain which is decentralization and more specifically DeFi.

2.3 Law and Policies in the Blockchain Ecosystem

From the previous segment, it is clear that environmental effects, legal presence, and political acknowledgment are intertwined. Blockchain products operate under a free market with little to no restrictions. Governments debate the laws, taxation, limitations, and security risks cryptocurrency poses but regulating a free market is never an easy choice and requires significant effort *(Truby, J., 2018)*. As far as the environmental concerns from the production of cryptocurrencies, officials have valid reasons to implement restrictions and punishments on the polluters. While this sounds relevant in theory, the actualization of such an action seems to be difficult *(Corbet, S., 2019)*. Due to the decentralized nature of the field, it becomes quite obscure as to whom those regulations should focus upon and to what extent *(Truby, J., 2018)*. Is it the users, the producers the hoarders, the online exchanges, or all of them together? Another possibility would be to incentivize the use of greener blockchain products or simply focus on the financial growth? *(Corbet, S., 2019)*, *(Lim, C., et al. 2019)*. These are all questions the legislators must answer before regulating this new market. The complexity of this topic calls for a holistic approach that can shed some light on the entry points and identify the challenges that must be addressed in terms of sustainability. Lastly, the importance of law and policy in this new technological field must be noted. Correct policies and fair law and enhance the future of blockchain but the opposite can also condemn it *(Truby, J., 2018)*.

2.4 Sustainable Supply Chain Management

Another key aspect of every blockchain is the sustainable supply chain management which integrates environmentally friendly practices which are also financially viable. This can involve raw material selection, development, transportation, and more *(Saberi, S., 2019)*. In the case of blockchain, many research works has been conducted through this approach and it has a close connection to life cycle thinking as well as the sustainability management theory which are two of the ways this research is approached, as will show in section 2.5. The dominant opinion amongst researchers thus far regarding blockchain is that blockchain has potential for sustainable supply chains but it still has a long way to go and a lot of traps to avoid *(Saberi, S., 2019)*, *(Kouhizadeh, M., & Sarkis, J., 2018)*, *(Lim, C., et al. 2019)*. In this case, the research differs, as it is focused on the cryptocurrencies and their structure from start to end, and not on the applications that blockchain has or might have in the future regarding other products or projects.

2.5 Research Approach

As mentioned above the core concept of the research is the analysis and comparison of four cryptocurrencies following a holistic approach. Therefore, the Life circle thinking *(Zhang, A. et al., 2020)* is here chosen, as it allows to go back to the extraction of raw

materials and calculate the costs in electricity there, among other relevant aspects that can have direct and indirect effects on the natural environment. Moreover, it allows examining potential wastes generated and what happens after the end of life, if there is one, since we are talking about currencies in the form of data. The cryptocurrencies do not take part in this last part upfront as they do not have a physical feature to recycle but the hardware used for their production does. It is multilevel research and life cycle thinking that makes it possible *(Imbault, F., et al, 2017)*, *(Heiskanen, E., 2002)*. As far as Sustainability management theory is concerned it allows to dive into the more technical part of the research and determine the sustainability levels for each mechanism and as result the sustainability levels for the currencies under investigation *(Williams, A., et al, 2017)*. Finally, the PESTLE analysis can frame the findings under a common ground to enable comparison among the cryptocurrencies and additionally shed some light on the legal areas that have not been deeply covered at present *(Alanzi S., 2018)*. In the following section, a more detailed description of what LCT, SMT, and PESTLE are, is presented.

2.5.1 Life cycle thinking

Life cycle thinking is a theory that takes a holistic image of an entire activity system. With this approach, the environmental and resource impact of the activity is evaluated. For clarity reasons, Life cycle assessment *(Rebitzer et al., 2004)* is the scientific method that enables a systematic perspective to distinguish the impacts to the environment from the production-consumption of any product/service/activity (figure 4). In this case, the activity is the production and use of currencies. The case of blockchain products follows a slightly different approach since the products do not have a physical form and they do not abide by the common vision of the 'cycle of life of a usual product *(Christensen et al., 2007)*. Due to them being blockchain products all their data are being automatically recorded, processed, and stored while at the same time remain traceable. That said, the process of identifying these data for cryptocurrencies that are not the most renowned can be deemed more challenging. Sometimes, and as is mentioned in this research, blockchain products have extremely different means of manufacturing which can lead to varying amounts of emissions.

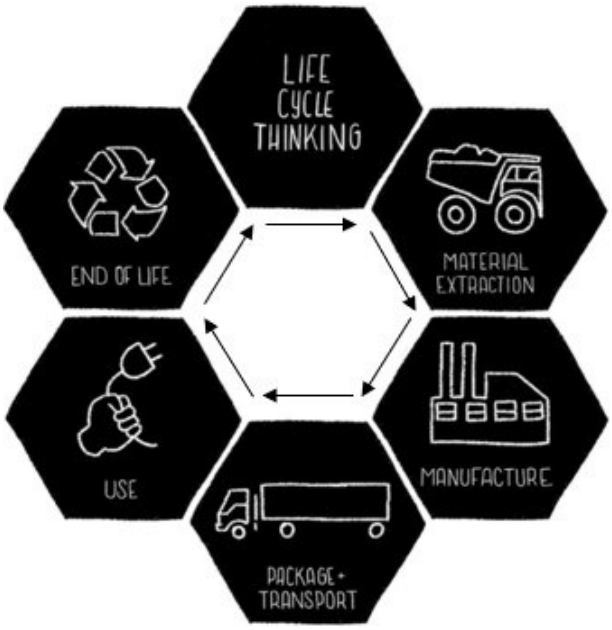


Figure 4 *: Life Cycle Thinking Illustration Created by Disrupt Design*

The Life Cycle Thinking theory consists of five main points:

Resource extraction and refining: Resource extraction and refining is simultaneously the first and last step in the life cycle thinking theory *(Rebitzer et al., 2004)*. It is the start as without these resources the production would be impossible. At the same time, it connects with the end of life of a product through the ability to salvage and recycle materials.

Manufacturing: This process is overly complicated one when it comes to LCA *(Rebitzer et al., 2004)*. In this case, manufacturing between cryptocurrencies is vastly different in terms of resources used but not as much when it comes to the method. Although the techniques are different, they all follow similar interpretations of the existing models or a combination of those *(Christensen et al., 2007)*.

Packaging and distribution: In the packaging and distribution, the differences are even larger as the lack of physical form makes this process almost trivial something that cannot be said for fiat currencies which require a full ecosystem for their safety *(Rebitzer et al., 2004)*.

Use: The use is the most crucial part of this theory *(Rebitzer et al., 2004)*. Each product caters to the needs of its user. In this case the usage of different uses of cryptocurrencies is described and through that gain insight for their environmental effects. What is the purpose of a product that is environmentally friendly but has hardly any practical uses and vice versa?

End of life: The end of life of a product is not the actual end but just another step in the creation of a more sustainable ecosystem *(Rebitzer, et al, 2004)*. While FIAT currencies follow this process as most products what happens with cryptocurrencies is unique. Due to them simply existing in the form of data they do not have an actual end of life.

Technically they are "immortal." That said there are some ways for such currencies to come out of circulation such as the process of burning[10].

2.5.2 Sustainability management theory

Sustainability management theory is all about being able to understand the impact and consequences of a particular action or product. It requires a multidisciplinary systematic approach and the ability to connect the economic, political, social, and ecological issues related to a product/process *(Williams, A., et al, 2017)*. This theory connects well with the subject at hand as the issue of cryptocurrencies, their usefulness, and their long-term sustainability. As to why this claim is true it is explained in the concepts below.

The core concepts of this theory that are used in the findings are:

Interconnections: The interconnected parts of a system determine how the system behaves *(Merali & Allen, 2011)*. Products and organizations always must balance between their self-preservation and their responsibilities towards the other actors and, in a broader scenario, the stakeholders. It is important to be able to comprehend these connections are key in achieving sustainability in all four approaches (economic, political, social, and environmental). In the discussion about currencies, this issue is upscaled due to the sear number of other ecosystems that are affected by the necessity for everyday transactions.

Feedback loops: Feedback loops are what helps to keep a system interconnected *(Kunz, et al, 2013).* When a part of it encounters some issues and fails to communicate these to the rest of the system it might cause a collapse. In the case of technologies used for the production and use of currencies these feedback loops are connected in the parameters mentioned in section 2.3.1.

Adaptive capacity: Adaptive capacity is the continuation of the feedback loops module as it revolves around the ability to maintain the basic structure (resilience) while at the same time adapt to new situations. *(Ehrenfeld, 2007)*, *(Whiteman, et al, 2004)*. The computing world exists in a constant state of change, much faster than the physical world. This creates some opportunities but some threats at the same time. That is why the data and blockchain system must undergo continuous improvements and fixed. The same cannot be said for fiat currencies which offer some stability, and the process of change is much slower.

Self-organization: Self-organization is "the ability of a system to structure itself, to create, to learn, or diversify" *(Meadows, 2009, p. 188)*. Complex adaptive systems can self-organize, learn from their experience, and adapt to changes in the external environment *(Ashton, 2009)*, *(Rotmans & Loorbach, 2009)*. In this case, we are talking of an extremely complicated system that handles millions of transactions each day with no potential for errors. The ability of such systems to self-organize is crucial for their long lives.

[10] Burning in the term used when a certain amount of cryptocurrency units are lost or forcefully removed from circulation. Such practices are mostly common in cryptocurrencies like USDT.

2.5.3 PESTLE Analysis

The PESTLE analysis is used in this research to complement the two frameworks of life cycle thinking and sustainability theory that may allow a holistic approach to the comparison of the four cryptocurrencies. According to Salem A., *"the analysis was given the name PESTLE and the acronym is formed by the initials of the six categories of macroeconomic variables included in the model (Political, Economic, Socio-cultural, Technological, Legal and Environmental)" (Alanzi S., 2018, p. 2)*. These six categories allow covering all the variables from life cycle thinking and sustainability management.

More detailed, the political aspect covers all kind of policies, laws, and restrictions which have a connection with cryptocurrencies and blockchain technology and is connected closely with the legal aspect. In this case, though, the laws are examined in more detail *(Alanzi S., 2018)*. This aspect is crucial because laws around cryptocurrencies are still vague due to the technology being something new and its operating systems are not fully covered by existing laws. The economic aspect includes economic growth, potential, interest, exchange, and inflation rates and value. The social aspect revolves around the type of users it attracts, the adaptation rates, the way cryptocurrencies are perceived by society, social barriers, and age distribution. The technological aspect covers the levels of innovation for each of the four currencies (BTC, ETH, ADA, USDT), their mechanisms, security and long-term viability, technological incentives, and awareness. These five aspects have more connections with the three out of four aspects of sustainability management *(Alanzi S., 2018)*. The final but most important (for this project) aspect in PESTLE analysis is the environmental, which ties together the life cycle thinking, the fourth aspect of sustainability management theory, and the answer to the main question of the research about the environmental effects of the previously mentioned cryptocurrencies.

Each of the four variables (currencies) are here examined under these six categories of PESTLE following the theoretical framework and then will be compared. This way, the strengths, and weaknesses of each variable against its competitors can be monitored comprehensively. Therefore, the conclusions about long-term sustainability can be extracted. In chapter 3, the research design of this project is elaborated and will connect the theoretical grounds with more operational steps to be deployed while executing the research design.

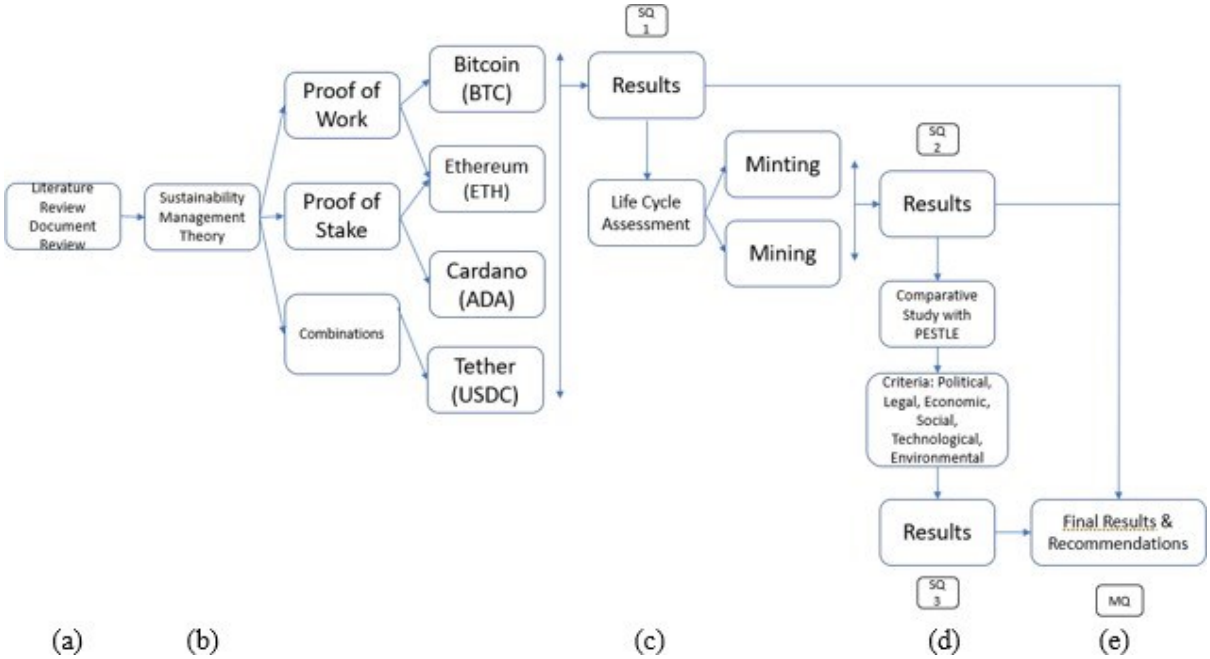
Chapter 3 : Methodology

This chapter describes the steps and the actions conducted to attain the research objective. It contains the research and analytical frameworks, the research strategy, and the methods used for the collection and analysis of the data.

3.1 Analytical framework

For the research questions to be answered a structured and well-formed way of thinking must exist. This structure is shown through the analytical framework below with the goal to guide and provided insight to the reader.

Figure 5 *: Schematic of the Analytical Framework*



The sequence of the data analysis is as follows:

a) The first step is deep research in the Literature. Relevant documents, papers, and articles will be used to give a good background since the topic at hand is something new and some people might be unfamiliar with the terminology.

b) Using the Sustainability Management Theory, the two main consensus mechanisms and their combinations will be analyzed always in relativity to the cryptocurrencies at hand. BTC ETH is using proof of work while ADA proof of stake and USDC. Ethereum though is in the middle of a process to transition to proof of stake and as a result, both of those will be considered. The results from this will be used for the final recommendations and provide the answer to sub-question 1.

c) After this step, the life cycle assessment is used as we will dive into the actual means of production for cryptocurrencies and their social, political, and environmental effects. Again, the results will be used for the final recommendations, and in this case, it provides the results for sub-question 2.

d) With the analysis of the mechanisms and means of production analyzed the comparison can take place considering the six criteria described in PESTLE analysis and thus achieving an all-around result in the research.

e) This ultimate step gathers all the findings and presents them. This is also the area that recommendations will be made for the results and expansion of the research in the future.

3.2 Research framework

In this sub-section, the methodological approach to comprehensively gathered information to answer the research question(s) is presented. In other words, a research framework is here applied to clearly illustrate the structure of the research plan in line with the needed information to answer the research questions. The framework is inspired by *(Verschuren & Doorewaard, 2010)* but slightly modified to fit in 5 fragments instead of 7 steps.

The framework of this research can be determined in **5 fragments**:

Fragment 1: Identify the research objective of the research

The goal of this research is to analyze and compare the long-term sustainability of four different cryptocurrencies (BTC, ETH, ADA, USDT) and their environmental, social, and political effects.

Fragment 2: Determine the nature of the research perspective

This research provides a comparative study focused on BTC, USDC, ETH, ADA, and their ecosystems. These variables will be explained, analyzed their usage, and evaluate their environmental, social, and political impact. For these reasons, the research follows the design-oriented approach.

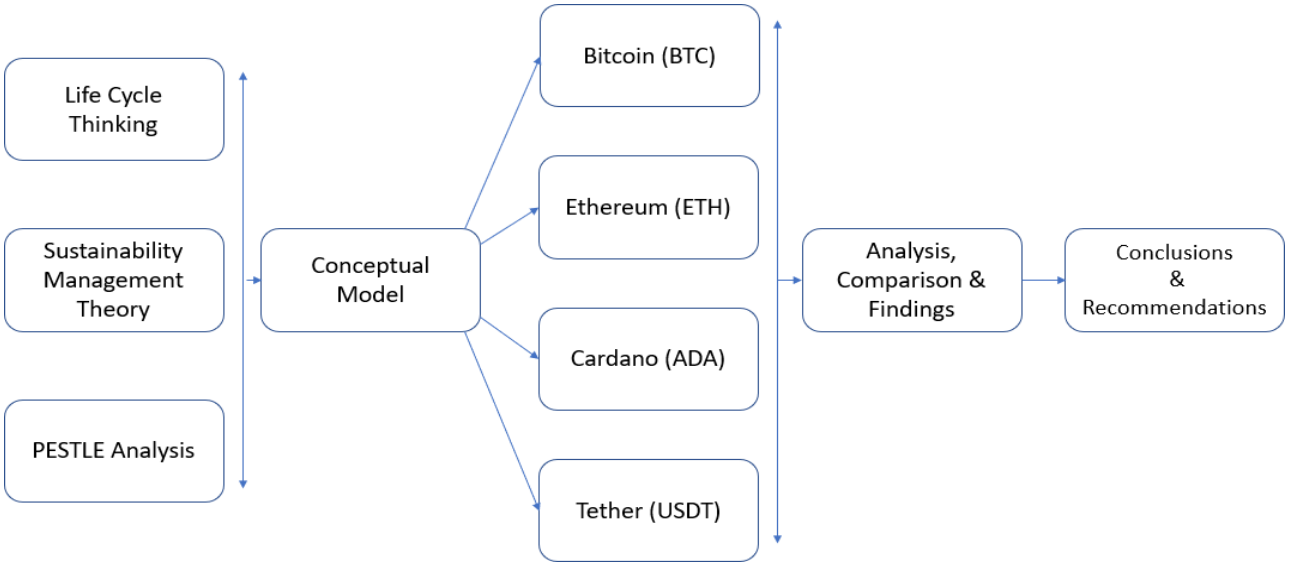
Fragment 3: Relate the sources of the research perspective

This is based on studying scientific literature and two theories will be used. For the concept of determining the raw resources, energy needs, and longevity of the currencies the life cycle thinking *(Heiskanen, E., 2002)* will be applied as it is important to determine the sources and the structure throughout the processing and production phase until the end of their life span with a special focus on the recycled materials. Next, sustainability management is used for the fair comparison in terms of economic, political, social, and ecological effects and how those are connected through feedback loops, interconnections, adaptive and self-organizing capabilities as mentioned in section 2.5.2. The tool that will be used is the PESTLE analysis as it provides all the necessary parameters to cover the theoretical frameworks as described in section 2.5.3.

Fragment 4: Complete the schematic and Presentation of the framework.

The schematic below shows how the LCA, SMT and PESTLE connect with each other but at the same time remain independent for each cryptocurrency and help answer the sub-questions.

Figure 6 *: Schematic Presentation*



Fragment 5: Map the research framework to assure that it follows logical and feasible steps:

Step a: Literature review about the points of the topic which are: Blockchain technology, cryptocurrencies, and consensus mechanisms.

Step b: Scrutinize the means the research objectives will be assessed. Since this topic is about comparing currencies that do not have the same form it is of the utmost importance that the means of assessment are logical and can be used for comparison.

Step c: Explore the results of the comparison conducted and explain the findings.

Step d: Add a discussion section for a more personal view on the subject and recommendations about future research.

Step e: Make certain that the model is robust and if not conduct the necessary changes.

3.3 Research strategy

The most important part of the research strategy is to be able to determine a pattern and set the rules for a fair comparison. The unique approach of cryptocurrencies regarding their means of production and their extreme volatility in price makes a one-on-one comparison impossible. For this reason, the comparative approach will be through data of the total production of each currency in a designated amount of time, in life cycle assessment terms, this corresponds to the functional unit. The unit in this case is created by calculating the energy required for the extraction of the raw materials and then comparing it with the rest of the energy that is consumed. Some exemptions to this reference in time are foreseen at this point but in the final report, the choices for the comparative analysis will be further elaborated if that turns to be the case. As far as the technological comparison features here are a bit more straightforward criteria with no expected exemptions.

3.3.1 Research unit and unit selection

The research will be focused on the four individual types of cryptocurrency coins. The production of cryptocurrencies is dominated by electricity consumption, so the main comparison will be done in Terawatts (TW).

The cryptocurrencies have been chosen according to some criteria. The market share, reputation, real-life applications, consensus mechanisms, and usage amount. The goal is to choose four currencies that can take the role of the ambassador for their respective technology.

With that in mind, the four chosen cryptocurrencies are BTC, ETH, ADA, and USDC, and the reasoning is as follows:

- Bitcoin (BTC) is the first cryptocurrency ever created and the first application of a blockchain. To this day it remains the dominant player in the cryptocurrency market and there is a rising concern about its environmental effects. It uses proof of work protocol which is energy demanding *(Digiconomist.com, 2021)*.

- Ethereum (ETH) is the second-largest coin by market capitalization, the first one to implement smart contracts, and the most actively used blockchain. It uses proof of work, and it is slowly transitioning to proof of stake mechanisms. It also acts as the starting point of many other blockchain products such as ADA.

- Tether (USDC) is a stable coin. Through minting and coin burn aims to be steadily valued at 1 dollar. It is one of the most used cryptocurrencies and has a different production mechanism that is discussed later on the paper.

- Cardano (ADA) is a known cryptocurrency that is based on the ETH blockchain. This newer generation of crypto has the goal to reduce transaction times and improve scalability.

3.3.2 Research boundaries

The main boundary of this research is that only four cryptocurrencies were examined, out of the thousand that exist. These four represent most of the abilities that blockchain-based cryptocurrencies have to offer in terms of sustainability and environmental, political, and social effects. Furthermore, in the life cycle thinking approach, in principle all the distinct stages and material required are to be briefly discussed but not in-depth due to time constraints and access to quantitative data. The specific environmental impact indicator for this research is the one of CO_2 emissions.

3.3.3 Research methods

This research follows the empirical approach used to examine the environmental, political, and social impact and long-term sustainability of different blockchain approaches. The method has a mix of qualitative and quantitative methods. Mostly qualitative methods were used and as the research reaches the point that environmental impact must be assessed then it will be mixed with the quantitative approach. Qualitative approaches are used to provide the reader with a holistic approach to the situation and as more technical terms and calculations are required the quantitative approach takes over. The results were presented in a mostly qualitative approach.

The methods used in this research as followed:

1) Desk research is the main source of information. The first part of the deck research was performed by searching the world wide web with the following keywords and their combinations: Bitcoin, Cardano, Ethereum, Tether, emissions, environmental, mechanism, consensus, social, political, transaction, whitepaper, sustainability, dominance, mining, minting, requirements, effects. More than one hundred articles and other documents were gathered. Out of those articles only a part is included in this thesis. In the second phase more specific terminology was researched such as: transaction speed, internal security, 51% attack, crypto life cycle, adaptability and more. The combination of articles and other sources chosen from the two phases can be found in the references section.

2) Interviews is another method applied in this study and follows an in-depth semi-structured technique. These type of interviews follows a series of questions related to the topic at hand and will focus more on the social, political and economic aspect of the research. This is required to collect relevant information, valuable data, personal interpretations of the current situation, and opinions about the future of blockchain. The questions asked are not set in stone and can be modified as the interview is underway and new conditions and questions appear. Nonetheless, the questions will still be relevant to the research topic and consider the answers provided by the informants thus far.

***Table 1** : Research methodology*

Sub Questions	Research method	Target group
In what ways do consensus mechanisms affect the long-term sustainability of these (BTC, ETH, ADA, USDT) cryptocurrencies?	Desk research, In depth Semi structured interviews	Private institutions, Academic researchers, Governmental reports
Following the life cycle thinking, what are the environmental impacts of 'mining' and 'minting' of each currency?	Desk research, In depth Semi structured interviews	Private institutions, Academic researchers
Do these products address the key requirements for sustainability and how do they compare with each other?	Desk research, In depth Semi structured interviews	Private institutions, Academic researchers, Governmental reports

3.3.4 Research material

The research material primary and secondary data are being used:

1) Primary data: Primary data are taken directly from a source and require a process following the research's scope. These data have not been processed before by someone else. In this case, these types of data are sourcing from the interviews. The questions asked through the semi-structured format follow the interview guidelines.

2) Secondary data: Secondary data are those data that are obtained indirectly because they have already been processed by someone else. This type of data is the main source that is used in this research.

3.4 Data collection

The data collected in the research is centered around the four cryptocurrencies under investigation and in two main forms. First the technical side of their production methods and secondary, their impacts. For the interviews, specific individuals were approached and thus a method of purposive sampling is used. The goal is to get as much information as possible and through that understand the implications of each system. In the table below the key criteria are presented for data collection (table 2).

Table 2 : *Data required and sources*

Research Question	Data Required to Answer the Question	Sources of Data	Data Access
In what ways do consensus mechanisms affect the long-term sustainability of these (BTC, ETH, ADA, USDT) cryptocurrencies?	Types of consensus mechanisms Purpose: These mechanisms are core to the creation of cryptocurrencies and understanding their differences is crucial	Literature	Desk research
	Production methods	Literature	Desk research
	Long-term performance	Literature	Desk research
	Environmental impact	Literature, People: software developers, environmental and economic analysts	Desk research Online Interview
Following the life cycle thinking, what are the environmental impacts of 'mining' and 'minting' of each currency?	Life cycle approach Levels and complexity	Literature	Desk research
	Approach (Resource extraction and refining Manufacturing, Packaging and distribution, Use, End of life)	Literature	Desk research
	Environmental impacts following the LCA model for distinct types of production and their sub-levels	Literature, People: software developers, environmental and economic analysts	Online Interview
Do these products address the key requirements for sustainability and if so to what degree?	Sustainability management requirements (Economic, political, social, and ecological)	Literature, People: software developers, environmental and economic analysts	Desk research Online Interview
	Separate analysis for each cryptocurrency	Literature, People: software developers, environmental and economic analysts	Online Interview

3.4.1 Selection of Interviewees and questionnaire

The goal of the interviews was to gain relevant insight into the topic from different perspectives. The plan was to conduct at least 5 interviews with a varied background. Crypto developers, bank employees or affiliates, and academic personnel. Unfortunately, due to time constraints, covid-19 regulations, and the unwillingness of participants, the number of interviews conducted was limited. Only 2 interviews were conducted successfully. Nonetheless, some of the potential interviewees that refused the interview provided relevant literature and material that helped the research.

3.4.2 Data analysis

The technique that was used throughout this process was that of content analysis. The first stage of the research involved a qualitative analysis of many pieces of literature related to the subject. Together with the primary data from the interviews helped to fulfill the goals of this research. The interview data were accessed through the transcripts. Details of the data analysis methods used per sub-question can be seen in table 3.

Table 3 : *Data and analysis methods*

Research Question	Data Required to Answer the Question	Method of Analysis
In what ways do consensus mechanisms affect the long-term sustainability of these (BTC, ETH, ADA, USDT) cryptocurrencies?	Types of consensus mechanisms Purpose: These mechanisms are core to the creation of cryptocurrencies and understanding their differences is crucial	Qualitive: Describe and compare the consensus mechanisms
	Production methods	Qualitive: Describe and compare the production methods
	Long-term performance	Quantitative: Evaluate the long-term performance of the cryptocurrencies investigated
Following the life cycle thinking, what are the environmental impacts of 'mining' and 'minting' of each currency?	Environmental impact	Quantitative: What is the environmental impact of each cryptocurrency
	Life cycle approach Levels and complexity	Qualitive: Analyze the approach and the complexity of LCA in the blockchain environment
	Approach (Resource extraction and refining Manufacturing, Packaging and distribution, Use, End of life)	Qualitative: Assess the approach that is being used
	Environmental impacts following the LCA model for distinct types of production and its sub-levels	Qualitive: Analyze and describe the environmental impacts
Do these products address the key requirements for sustainability and if so to what degree?	Sustainability management requirements (economic, political, social, and ecological)	Qualitive: Assess the approach that is being used
	Separate analysis for each cryptocurrency	Qualitive: Analyze and compare the results using PESTLE analysis for long-term sustainability

3.5 Ethical Considerations

This research contains material and sources gathered from interviews. The study fully complies with the ethical principles set out in the University of Twente's Research Ethics Policy, which involves providing the interviewee with a consent form for the interview approval. All the interviewees were briefed about the process and the questionnaire, and the consent form were handed out before the interview. The option to withdraw from the interview at any time was always available with no consequences for the interviewee. The interviewee's privacy was and is respected. Any information that was designated as confidential during the interview is not disclosed in the document.

Chapter 4 : Findings

All the results and the answers to the sub-questions are presented in this chapter. They are based on the content analysis of the data collected from the semi-structured interviews and desk research. It was conducted by reviewing diverse reading material. It includes peer-to-peer articles, whitepapers of the investigated cryptocurrencies, sustainability reports, and other relevant sources provided of course that they are valid and backed by data and are official. The literature provides details and data for each one of the currencies and the technologies that are being used. This chapter does not include a discussion on the results. The main question and sub-questions are answered in a sequence. The first part revolves around the core consensus mechanisms and answers the first sub-question. It is followed by the impacts the production of cryptocurrencies has under the LCT theory and focuses on the second sub-question and finally an analysis of the four cryptocurrencies (BTC, ETH, ADA, USDT) following PESTLE with the goal to answer the third and final sub-question.

4.1 Blockchain: A constantly evolving technology

Blockchain is an innovative technology with only a few years of life *(ElBahrawy, A., 2017)*. It is only natural that when breakthroughs transpire regularly, misconceptions and misunderstandings occur. Its first implementation and the most renowned product is the cryptocurrency named Bitcoin in 2008. Since then, blockchain technology has found a lot of support and a lot of critics as well. It continues its process of mass adoption, and the developers strive to find new applications *(Huang, J., et al, 2019)*.

Its applications include, but are not limited to, data validation, data sharing, certifications, records, payments, identification, and digital currency. At the same time, its weaknesses and areas of challenge are being documented and discussed *(Houben, R., & Snyers, A., 2018)*. In March of 2021, the private company Tesla -which produces electric vehicles- accepted BTC as a valid means of payment for electric cars only to withdraw this statement a few months later (*May 12, 2021*) when the environmental concerns surrounding BTC came to the spotlight *(Ossigen J., 2021)*. A question arose from the stance of Tesla because the energy consumption issues of BTC were a known issue before the company decided to accept it and not a well-kept secret *(Nakamoto S.,*

2008). More information on this matter is provided in sections 4.2.1 and 4.3 where the political and environmental effects of BTC are shown.

As far as acceptance at a governmental level, El Salvador in June of 2021 accepted BTC as a legal tender and other countries are in internal discussions if they should do the same *(Aleman M., 2021)*. The process of being accepted by the general public, governments, and big corporations is still in its infancy. Amongst this commotion, it is important to identify the effect cryptocurrencies have and try to limit the negative effects. For this process to have correct identification must take place. In this research, the first step for this identification is to examine the consensus mechanisms of each one of the four currencies.

4.2 Consensus Mechanisms: Long-term sustainability

In this part, the consensus mechanisms that are being used by the four cryptocurrencies under examination are analyzed based on the SMT. The interconnections, feedback loops, adaptive capacity, and self-organization (see section 2.5.2) are the core concepts of this theory. Due to the complexity of these mechanisms the analysis will not go into a deep technical level as this has been done before. The only instance that more details are provided is when a core concept requires it. This section aims to answer the first sub-question: In what ways do consensus mechanisms affect the long-term sustainability (as described by SMT) of these cryptocurrencies (BTC, ETH, ADA, USDT)?

4.2.1 Proof of Work

Proof of Work (POW) is the consensus mechanism used by many cryptocurrencies, including Bitcoin *(Böhme, R., et al, 2015)*. A basic description of the POW protocol can be elaborated as follows: An entity has to prove through demonstration (to the verifier) that a certain action or a certain amount of computational work has been completed in a specific amount of time *(Huang, J., et al, 2019)*.

Two main variants exist, the challenge-response protocols and the solution-verification protocols.

In the first variant, the verifier which in the cryptocurrency ecosystem is usually a server, sends an item that requires a solution. The client, in this case, after finding the solution sends back the item solved. The server verifies the solution and the orderly usage of the item. If the verifications are completed successfully the rewards are being sent to the client. *(Böhme, R., et al, 2015)* In this case, there is a direct line of communication between the client and the server and a constant back and forth until the loop is completed. In the case of solution verification, protocols reject this. In this case, the item or problem that requires a solution is created and then solved by the client. It is communicated to the receiver only if and when it is requested.

Both of these interconnected protocols have strong self-preservation but also require a lot of computing power to operate. The need for constant computing power to solve

these hashes creates the need for a lot of electrical power which under different circumstances could have been used for other purposes. This impacts negatively not only the environment, but the society and economy of the areas affected by either the lack of electricity or the health risks that naturally occur around fossil fuel power plants. Although security is generally good some risks do exist which the system cannot adapt to *(Gervais, A., et al, 2016)*. In the crypto ecosystem, a democratic voting system exists based on the number of coins or tokens a single entity control. Theoretically, if a single entity or a group with common interest manages to hold at least 51% of voting power they can effectively decide which transactions get confirmed (or not) in the blockchain. This is extremely difficult to happen in blockchain that is too big, such as Bitcoin or Ethereum. It is a serious threat to small cryptocurrencies though due to their lower total value and lack of competition. In this case, someone achieving 51% voting power and essentially controlling the system is substantially easier *(Xu, J. J., 2016)*. This democratic system has a lot of benefits as well. It allows the blockchain to self-organize, learn, and adapt to changing situations. This flexibility allows for the cryptosystem to continue evolving although it is not always easy as shown in section 4.3 when the mining effects are talked about *(Gervais, A., et al, 2016)*.

Overall, the POW protocols are self-sustained for the most part and have integrated systems to combat stagnancy and most issues. Where it fails though is the energy consumption as the amounts of electricity consumed are huge. Only BTC is estimated to use more than 120TWh as of 28 June 2021 *(Digiconomist.com, 2021)* which is more than Argentina. This energy issue is not present in the other two consensus mechanisms.

4.2.2 Proof of Stake

Proof of Stake (POS) protocol is specifically designed for blockchains and thus has a different approach to the validation procedure. It tries to solve the same issues with the POW mechanism without consuming plentiful quantities of energy or producing substantial waste *(Saleh, F., 2021)*. As mentioned before, every blockchain transaction must be validated and attached to the blockchain. In the case of POW, this happens through the usage of computing power *(Böhme, R., et al, 2015)*. POS requires its validators to own a certain amount of blockchain tokens. It was first used in 2012 and since then a lot of blockchains implement it. The most notable example is the Ethereum network which aims to switch from POW to POS mechanism. ADA is another blockchain token that is based on this concept.

In this case, the user who wants to participate in the validation of a POS blockchain first must buy a minimum required amount of the cryptocurrency they want to be involved with. For security and spam avoidance reasons, usually, this quantity is large and may prove difficult for a retail investor to participate. For this reason, the so-called “stake pools” have been created. There, a group of users combine their capital and share the rewards given to them *(Saleh, F., 2021)*. Usually, such activities require the locking of funds for a specific amount of time. Additionally, if a validator is confirmed to try to negatively impact the network through their actions their capital can be slashed. The validation procedure, just like in POW, involves a certain amount of randomness *(Brünjes, L., et al, 2020)*. This type of interconnection in the system can dissuade a potential user who wants to have its capital ready for use at any moment. While the system is secure from a technical standpoint and resilient to any kind of malware attack it falls under the same risk as a POW project. The potential for a single entity to control

the majority of a token and thus controlling it. Since the one restriction to enter a POS cryptocurrency as a validator is a capital availability it is objectively easier to gain control since the requirements in POW include specialized hardware, energy availability, and electricity costs. Some of those concerns' security is being addressed by protocols such as "Ouroboros" which aims to achieve the same level of security POW cryptocurrencies have *(Kiayias A., et al, 2017)*.

4.2.3 Proof of Reserves and Proof of Burn

This mechanism's definition is quite straightforward. It confirms that certain actions have taken place and the necessary evidence that their capital is indeed secure (Dutta, A., 2019). In the case of Tether, it provides evidence that the total amount of USDTs in circulation is always 100% backed by an equal or greater amount of FIAT currency (Tether, 2016). As for the process of how this is achieved most sources revolve around what the company claims and thus can be biased. Some of the information provided is outdated as the webpage they site is nonfunctioning anymore. Nevertheless, Tether claims that all USDTs (issued, redeemed, existing) and the transaction history are publicly auditable. Another bank account receives and sends FIAT currency to all these users that redeem or purchase USDTs directly from the company. All the tools that Tether provides to validate these claims are no longer working *(Tether, 2016)*. This creates questions about the company practices but as far as the consensus mechanism is concerned it is valid and can be implemented.

Proof of Burn is a mechanism that is used to destroy certain amounts of cryptocurrencies in a valid and easily verifiable manner *(Karantias, K., et al, 2020)*. The process involves two steps. First, a burn address is generated. This is an address in which the keys to access it are not available and any deposit done in this account is removed from circulation forever *(Pillai, B., et al, 2020)*. This is primary used by Tether as issuing and burn tokens is crucial to keep the stable price against the US dollar. This can be done for any cryptocurrency though. If an address is created and then for some reason, it becomes inaccessible those coins have been permanently removed from circulation. Of course, this can happen by mistake, in which case it is not a POB example.

4.3 Cryptocurrency Life Cycle

This section discusses the life cycle of cryptocurrencies, from their creation till their end of use. More precisely, starting from the resources required, the manufacturing process, the distribution, their usage, and what happens when their life cycle ends. The way cryptos approach this thinking is slightly different than a usual product would e.g., an umbrella, due to the lack of physical presence. Nonetheless, the main structure remains the same. First, the resources required for each consensus mechanism and cryptocurrency are discussed. Secondly, the manufacturing process which is split into two main categories, mining, and minting. Followed by the distribution process of the four cryptocurrencies and their systems. The different usages, cryptocurrencies are discussed next and finally what happens when the end of their life is reached. This section aims to address the second sub-question: Following life cycle thinking, what

are the environmental impacts of 'mining' and 'minting' of each currency (BTC, ETH, ADA, USDT)?

4.3.1 Resources Requirement

Due to the complexity of the materials used and the vast number of different models this research does not dive into the exact components and where they came from. Instead, focuses on explaining how and why they are used. The first BTC coin was mined using a CPU and later GPUs started to be used due to their much higher processing power *(Mittal, S., & Vetter, J. S., 2015)*. Since then, special miners called ASICs have been created which overpower both CPUs and GPUs. While GPU and CPU mining are still present the focus will be the ASIC units as they are the most cost-effective *(Taylor, M. B., 2017)*. The prices can vary from a few hundred US dollars and reach more than 10.000 US dollars. The prices were taken from Amazon.com and BuyBitcoinWorldwide.com which specializes in selling mining equipment. The high demand for this kind of product can often lead to a lack of available models and as a result, inflate the price. The average life span is 3 to 5 years. The energy consumption of the ASIC unit depends on several factors and can vary greatly. These are quality of the materials, temperature, TH/s, and the degrading life span *(Taylor, M. B., 2017)*.

As mentioned throughout the document the energy consumption is a constant struggle for POW cryptocurrencies and especially BTC. Various sources indicate different amounts of energy consumption for BTC. For example, *Digiconomist.com (2021)* calculates 135,12 TWh (July 7) while the *CBCI (2021)* from Cambridge Centre for Alternative Finance estimates 67,22 TWh (July 7). The same amount of contradictory data exists when it comes to the type and amount of energy that is consumed. For example, while one report from 2019 estimates that 79% of BTC's energy is carbon neutral *(Bendiksen, C., & Gibbons, S., 2019),* the *CBCI (2020)* suggests a figure is closer to 39%. Each estimation uses a different model, so no one really knows how much hardware or energy is used. This statement was confirmed by Florian Helfrich, a PhD candidate at the University of Twente who mentioned that no-one has successfully calculated how much energy and resources are needed for the Bitcoin network to operate. Any attempt to answer this question led to incomplete results.

4.3.2 Identification of the Manufacturing Process

The next step is to identify how cryptocurrencies are and created and understand better how the resources discussed previously are implemented in the process. From the literature, we can identify that the main ways cryptocurrencies are created are mining and minting *(Köhler, S., & Pizzol, M. 2019).* Before the analysis starts it is important to note once more minting is part of the mining process that occurs after the mining of a particular coin or block is complete. For this comment to make more sense the exact functions of mining and minting are necessary. Their nature is presented in the following paragraphs.

Mining:

In general it can be said that people are familiar with the term of "mining" which usually refers to the extraction of valuable resources from the Earth. In the case of cryptocurrencies though, the word gains a whole different meaning. In this case, mining is the process of producing new coins or tokens for a cryptocurrency through the usage of electric power *(Konoth, R. K., et al, 2018)*. To take part in this activity, people use their computers (nodes) and more specifically their CPUs or GPUs' computing power to become transaction processors and validators *(Investopedia, 2021)*. With the description of the materials required to create this hardware and the large energy consumption is needed for their operation the cost to the environment is notable. This significant resource expenditure provides a mined cryptocurrency with real value. This inherent value is not always greater than the cost of the resources spent. This does not deter companies or individuals from continuing such operations due to the volatility in the cryptocurrency prices and the upward trend the crypto market has since its birth *(Fontanills, G. A., & Gentile, T., 2002)*. All the interviewees, who participated in this research, agreed that if there is profit to be made mining requirements and difficulty will continue to rise despite the environmental concerns. As mentioned in the literature review (sections 2.1.1, 2.1.3, 2.1.4) the two largest cryptocurrencies, in terms of market dominance, hash power expenditure, and adoption, BTC and ETH use POW which entails that mining is used in their production. While researchers cannot pinpoint the exact amount of energy usage of these two cryptos it is accepted that they are by far the largest polluters in the crypto market as well. The vast majorities of estimations calculate BTC's, and ETH's electrical energy consumption is over 130 TWh combined (this takes 2021 scaling in mind) *(Fairley, P., 2018)*, *(Mora, C., et al, 2018)*, *(Corbet, S., & Yarovaya, L. 2020)* and the carbon footprint over 75 Mt CO2 *(Digiconomist.com, 2021)*.

Minting:

There is another coin generation process that avoids power-hungry mining. This process relates to the POS mechanism and is called minting. Minting is the process of manufacturing coins with some type of stamping for identification. Cryptocurrencies do not have a physical form, but the premise of the process remains the same *(Deuber, D., et al, 2020)*. As mentioned in section 4.2.2 in the POS for someone to participate in the production he must stake a minimum amount of said cryptocurrency. Then, randomly selected participants record and verify data and information on the blockchain *(King, S., & Nadal, S., 2012)*. Although this process does not use anywhere near as close as much energy (source) as mining it still has some drawbacks. These mostly involve the financial risk that occurs when a participant locks its funds in a stake pool. This inability to move or trade cryptocurrencies while staking is in progress may drive some participants away. If the staking process is completed successfully the system provides rewards to the participant *(Deuber, D., et al, 2020)*, *(Abraham, I., & Malkhi, D., 2017)*. This is the type of system ADA is using. Stable coins such as USDT although they do mint coins follow a slightly different approach. The need to be able to constantly keep the price pegged (see section 2.1.4) against the dollar requires constantly generating and burning tokens. Although Tether has some liquidity pools the constant balancing occurs internally.

4.3.3 Distribution

Ledgers have been used by humanity for thousands of years to store, record, and preserve deals and contracts. Since computers were created these types of data are stored electronically and lack a physical presence. Blockchain is no different and it is using a system called "Distributed ledgers." Contrary to the centralized ledgers that are most common distributed ledgers are shared and synchronized amongst multiple entities *(Mainelli, M., & Smith, M., 2015)*. This type of system eliminates the need for a central authority and eliminates the risk of manipulation since it does not have a single point of failure. In the centralized ledgers, if the central system succumbs to an attack, it can be compromised and fail. When a new transaction is requested and authenticated in a blockchain a "block" is created. This block represents the transaction and contains its data, the cryptographic hash of the previous block, and a timestamp. This block is sent to every participating node and is validated. If the validation is successful the participators receive a reward, and the block is added to the blockchain. The update is distributed to the network and the transaction is complete *(Beck, R., & Müller-Bloch, C., 2017)*. As every action consumes energy albeit limited. Another type of cost the transaction cost which is of monetary nature. These costs can vary on the type of cryptocurrency, traffic, and validation speed.

4.3.4 Usages

Blockchain products have many different applications and usages, but the focus of the research is BTC, ETH, ADA, and USDT. The primary usage of every currency is to be used for trading and this remains true in this case as well. Cryptocurrencies have some notable advantages and disadvantages over their FIAT counterpart *(Chuen, D. L, et al 2017)*. The most important advantage is DeFi, they operate in a peer-to-peer manner, and intermediates are eliminated for any transaction. This involves the risk of losing funds in the transaction due to the lack of mechanisms to protect the user from sending coins or tokens to the wrong address. Another notable difference is privacy issues. All the blockchains discussed in this research have their transaction data public which provides transparency. The issue encountered here is the lack of privacy. If the user of a crypto address is known then every single transaction this user has made or will make becomes public knowledge *(Bach, L. M., et al, 2018)*. Some cryptocurrencies that offer privacy do exist such as Monero. Transaction speed varies amongst cryptocurrencies and scalability opportunities are based on the consensus mechanisms. An additional point of interest is the transactions costs. Cryptocurrencies that use POW mechanisms have a much higher cost per transaction than the rest. This is evident by the fact that ADA has potential to have thousands of transactions per second *(Kiayias, A., et al, 2017)* while the other 3 vary between 4 and 30 TPS *(Coinmarketcap.com, 2021)*. The high transaction costs and limited supply have driven Bitcoin to be considered more of a *store of value*[11] than a currency. On the opposite side, the Ethereum network wants to avoid this and aside from environmental concerns, the reduction from transitioning to a POS mechanism is important.

[11] This term is used for assets, commodities or currencies that can be stored and traded without losing their value over time. One such example is gold.

4.3.5 End of Life Cycle

The end of life of a product arrives when a product is near or reached its lifecycle. This means that the product cannot be used anymore, does not receive updates, cannot be traded or all of the above together *(Dangelico, R. M., & Pontrandolfo, P., 2010)*. This is a natural process and cryptocurrencies are not any different. Their end of life can be categorized into two. First, when the hardware used for production reaches its end, it has to be replaced. These types of hardware have a few recycling opportunities *(Taylor, M. B., 2017)*. The second category is cryptocurrencies themselves. Due to the lack of physical form, their end of life is different compared to a regular product (e.g., a smartphone). The way a cryptocurrency can reach its end of life is if the project is abandoned, the price for some reason reaches zero, through the process of burning *(Karantias, K., et al, 2020)*, and finally misplacement. Misplacement refers to the case of a user cannot access their wallet anymore. In all of the above cases the coins or tokens technically still do exist but in a form that renders them unusable and non-recyclable. The electricity that was used for their productions can never be recovered.

4.4 Final Comparison between Bitcoin, Ethereum, Cardano and Tether

In this part, using the results from the previous sections, literature, and interviews the comparison of the four cryptocurrencies is completed. PESTLE analysis is being used and presented in two steps. First a table with an overview for each cryptocurrency with brief mentions of the important parts in each sector (political, economic, social, technology, legal, environment). Below each table, the brief comments the table are expanded and explained. All market indicators presented below were sourced from (*Tradingview.com, 2021)*, *(Coinmarketcap.com, 2021)*, *(Pooltool.io, 2021)*. These sources use live data (July 7, 2021) drawn from the blockchains and are subject to change at any moment. This section aims to answer the third and final sub-question: Do these products (BTC, ETH, ADA, USDT) address the key requirements for sustainability and how do they compare with each other (using the PESTLE analysis)?

Admittedly this was by far the most complex part of this research as the need to compile all the knowledge gained from the document thus far and add new information was proven quite challenging. The constant evolvement of the crypto space did add to this difficulty.

Legal component: All four cryptocurrencies (BTC, ETH, ADA, USDT) examined fall under this definition. As a stable coin USDT has some added guidelines which are mentioned in section 4.4.4.

Legislation of cryptocurrencies is still in its infancy and far from a universal consensus. For example, in the US states and even different governmental authorities have varying views and interpretations for what cryptocurrencies are. The US Security and Exchange Commission considers some cryptocurrencies to be securities while the Internal Revenue Service describes cryptocurrencies as property and issues guidelines for their taxation. These differences are actively trying to be resolved through the “Eliminate Barriers to Innovation Act of 2021” bill. The focus being what makes a cryptocurrency a security or commodity.

In EU, the situation is simpler. Cryptocurrencies have their own definition through the "Fifth Money Laundering Directive." According to the definition they must not be issued by a central bank or public authority. Secondly, their value must not necessarily be attached to an existing FIAT currency but simply be accepted as means of transaction by legal entities and finally they can be stored, traded, and transferred electronically. It important to note that all interviewees mentioned that since the key points of cryptocurrencies is the security, privacy and decentralization having regulation can compromise these points up to a certain degree.

4.4.1 Bitcoin PESTLE Analysis

***Table 4**: Bitcoin PESTLE Analysis*

Political	Economic	Social	Technological	Law	Environmental
Legal Tender in EL-Salvador China Bans Bitcoin mining	Most dominant cryptocurrency in the market High transaction cost compared to Tether and Cardano	Most well-known cryptocurrency Considered a store of value	Limited updates and system upgrades Lack of consensus amongst the miners Low transaction speed mitigated by lighting network	Unregulated Falls under the EU definition of cryptocurrencies	Most polluting cryptocurrency No plans to address environmental concerns Energy usage is directly connected with market competition

Political:

Bitcoin, as mentioned throughout the document, is the only cryptocurrency to have been accepted as a legal tender by a country, El Salvador *(Aleman M., 2021)*, and large corporations such as Tesla *(Ossigen J., 2021)*. Other countries consider following El Salvador's example. A point of interest is that this type of acknowledgment is very recent, with both occurring in 2021.

Another recent action that shacked the cryptocurrency market in 2021 is China's ban on mining Bitcoin. An action that created a lot of uncertainty in the market and affected the price of all cryptocurrencies. At the same time, miners search for countries who can sustain and would welcome their business model.

Economic:

BTC has a maximum supply of 21 million units. Currently 18.760.650,00 units are in circulation and the total value of its circulating supply is approximately 623 billion US dollars. Each unit's current price is around 33 thousand US dollars. Due its difficulty and excessive costs to transaction with Bitcoin can be considered a store of value similar to gold instead of everyday currency. It by far the most dominant cryptocurrency with it controlling more than 44% of the total market. An issue Bitcoin has to deal with is its high transactions costs when comparted to other cryptocurrencies like ADA.

Social:

The total amount of addresses that hold BTC in the network are over 38 million with over 950 thousand off them being active the past 24 hours.

In order for changed to made in the systems of BTC and consensus amongst the miners must be achieved *(Böhme, R., et al, 2015)*. Due to the considerable number of miners and high levels of decentralization this has been proven to be difficult. From one side it makes the BTC less vulnerable to malicious attacks but on the other it stops updates and possible innovations that might improve the network.

As mentioned by H. Florian Bitcoin is by far the most dominant cryptocurrency in the academic world which leads to ignorance for other cryptocurrencies. A statement which only strengthens the claim that the majority of people equalize the term Bitcoin with the term cryptocurrency.

Technology:

Bitcoin network uses the Proof of Work consensus mechanism *(Huang, J, et al, 2019)*. Each is BTC unit is produced through mining and practically exchanges hardware and energy consumption to produce new units through a problem-reward system. BTC, despite being the centerpiece of the crypto world, has not created any innovations worth mentioning. This is mainly due to the lack of consensus as mentioned above.

Transaction speed in another issue that Bitcoin has to deal with and up to a point has succeeded with the implementation of the lighting network. It is a "layer 2" paying protocol which allows faster transactions in the network.

Environment:

BTC is by far the number one polluter in the crypto ecosystem with over 120 TWh used in its mining activities *(Digiconomist.com, 2021)*. Its energy consumption is related to the hash-rate of the network which in turn relates to the amount of competition. The more mining units compete with each other for the same block solution the more energy intensive the whole procedure becomes.

These effects have a direct connection with the mining ban China enforced and Tesla's decision to stop accepting Bitcoin as means of payment for their product.

4.4.2 Ethereum PESTLE Analysis

***Table 5**: Ethereum Pestle Analysis*

Political	Economic	Social	Technological	Law	Environmental
China Ban on Bitcoin affects Ethereum as well	Second most dominant cryptocurrency in the market High transaction cost compared to Tether and Cardano though the gas system	Mostly unknown to the general public Well-known in the cryptocurrency ecosystem	Constantly developing upgrades and drives innovation Most active blockchain with a large ecosystem around its smart contract platform Low transaction speed issue which is addressed by the transition to POS	Unregulated Falls under the EU definition of cryptocurrencies	Second most polluting cryptocurrency Aims to reduce its energy usage by 99,5% with its POS upgrade Environmental concerns are part of the agenda

Political:

Politically Ethereum has a limited presence. Despite being one of the largest cryptocurrencies and highly active in the development department it gets overshadowed by BTC.

An example of this is the fact that BTC mining ban in China directly affects ETH and all other POW cryptocurrencies. The ban, although focused on BTC, reflects all the mining facilities despite what cryptocurrency they mine.

Economic:

ETH does not have a maximum supply. Currently 116.603.798,00 units are in circulation and the total value of its circulating supply is approximately 261 billion US dollars. Each unit's current price is around 2,2 thousand US dollars. It is the second largest crypto second only to BTC. It does have the same issue with Bitcoin as its transaction costs are high and it aimed to be solved through the transition to POS.

Social:

ETH exists in around 160 million addresses and 798 thousand of them have been active in the past 24 hours. Ethereum aims to become something more than a simple transaction of means or store of value and instead want to become a platform for any kind of application that can store data in a secure manner *(Buterin V., 2013)*, *(Antonopoulos, A. M., & Wood, G., 2018)*.

Technology:

Ethereum network uses the Proof of Work consensus mechanism, but it is in the middle of the transition process to Proof of Stake. ETH uses the same procedure as BTC to generate new units.

The first network to implement smart contracts was Ethereum. Smart contracts are protocols that allow the automatic execution, control, and documentation of events and actions according to the terms of a contract. ETH continually strives to improve its network capabilities with constant updates *(Antonopoulos, A. M., & Wood, G., 2018)*. An example of this is the Byzantium hard fork which improved the speed and security of ETH tokens. Ethereum's smart contract ecosystem is the largest in crypto space at the moment.

Ethereum network is able handle approximately 30 TPS. Alongside environmental concerns and energy reduction this is another reason ETH is transitioning to a POS protocol. POS allows for much higher transaction speed and less transaction costs.

Environment:

ETH expect being the second largest cryptocurrency in value it is also the second largest cryptocurrency in energy consumption. According to *Digiconomist.com (2021)* the Ethereum network consumes more than 55 TWh. The network acknowledges this issue and the reduction of energy consumption by 99,5% is one of the main effects the transition to POS will provide *(Ossigen J., 2021)*, *(Beekhuizen C., 2021)*.

4.4.3 Cardano PESTLE Analysis

***Table 6**: Cardano PESTLE Analysis*

Political	Economic	Social	Technological	Law	Environmental
Presence through deals with governmental institutions such as Georgian and Ethiopian ministries Cardano is legitimized through these deals	Fourth largest crypto in the market Low transaction costs	Unknown to the general public Well-known in the cryptocurrency ecosystem	Constantly developing upgrades and drives innovation Second most active blockchain Very high potential transaction speed through Ouroboros	Unregulated Falls under the EU definition of cryptocurrencies	Green cryptocurrency with minimal emissions when compared to Bitcoin and Ethereum Environmental concerns are part of its agenda

Political:

The Cardano network has achieved some notable collaborations with the Ministries of Education of Georgia *(Forbes, 2019)* and Ethiopia *(Sorkin, R. A., et al, 2021)*. These contracts have provided the network with legitimacy.

As mentioned by an interviewee 1 who is employed in the banking sector and requested anonymity, Cardano aims to collaborate with governmental institutions as a means to legitimize and strengthen its product before regulations come to effect.

Economic:

ADA has a maximum supply of 45 billion units. Currently 32.704.886.184 units are in circulation and the total value of its circulating supply is approximately 44 billion US dollars. Each unit's current price is around 1.4 US dollars. Its market dominance is around 3% and remains amongst the top 5 currencies by total value.

Social:

ADA currently has 1,822 stake pools active. The number of users in each pool varies and depends on the available pledge amount, total amount, fees, rating, and status. The usual number of delegators in each pool is 108 but this can vary as small population stake pools exist as well.

Technology:

Cardano network uses Proof of Stake consensus mechanism *(Saleh, F., 2021)*. ADA production is done through staking pools where each user invests an amount of capital, locks its funds and processes transactions in the network.

Cardano is currently trying to implement smart contracts in its system just like Ethereum. The first successful test has already taken place with the Cardano Alonzo smart contracts platform *(developers.cardano.org, 2021)*.

ADA transaction speed is currently 7 TPS but can reach over 250 TPS. Additionally, the Ouroboros Hydra *(Kiayias, A., et al, 2017)* protocol released in 2020, the amount of transaction per second can multiply the existing system capabilities. It must be noted that the system operates with 7 TPS for the sole reason that this speed is enough to cover the available transaction traffic.

Environment:

ADA advertises itself that is tries to solve problems related to the environmental concerns and sustainability of cryptocurrencies. Due to its POS protocol its production does not require special hardware and vast energy consumption *(Saleh, F., 2021)*.

4.4.4 Tether PESTLE Analysis

***Table 7**: Tether PESTLE Analysis*

Political	Economic	Social	Technological	Law	Environmental
Refused to be audited by neutral sourced Involved in a few scandals	Largest stable coin in the market Third largest cryptocurrency overall Low transaction costs similar to Cardano	Unknown to the general public Infamous in the cryptocurrency ecosystem	It belongs to a different category (stable coin) than the other three cryptocurrencies examined. No active technological development	Unregulated Falls under the EU definition of cryptocurrencies And the asset referenced token definition Legal issues with the state of New York and other institutions due to its scandal involvement	Green cryptocurrency with minimal emissions when compared to Bitcoin and Ethereum No Environmental agenda

Political:

Tether is currently under investigation by numerous US governmental institutions for its involvement into a number of scandals. The most prominent is the Bitfinex scandal which involved 850 US dollars and despite initial claim it was proven that both companies were own by the same individuals *(Vigna P., 2019)*. Questions also exist about the reserves Tether possesses and if all USDTs in circulation are backed. These questions exist due to the constant denial of Tether to provide audits.

Economic:

USDT does not have a maximum supply. Currently 64.469.767.617,00 units are in circulation and the total value of its circulating supply is approximately 62 billion US dollars. Each unit's current price is 1 US dollar and remain stable since it is pegged against it *(Tether, 2016)*.

Its primary uses are an easier way to buy cryptocurrency with FIAT currency and it also provides an alternative to people who do not want to keep their savings in traditional currencies but the prefer the benefits blockchain offers.

Social:

The total amount of addresses that hold TETHER in the network are around 3.2 million with just under 90 thousand actives in the past 24 hours. It remains relatively unknown to the general public and has a negative reputation in the blockchain community.

Technology:

Tether is based on the Bitcoin network but uses two main consensus mechanisms called Proof of Reserves and Proof of Burn *(Tether, 2016)*. In this case the tokens are generated and burned according to the company's reserves. Due to its unique price approach USDT belongs in a different category the stable coins *(Bullmann, D., et al, 2019)*. Tether operates between 4 and 20 transactions per second and has no significant scalability. In contract to the other cryptocurrencies in this analysis this does not affect it due to its different nature.

Law:

As with every cryptocurrency Tether's legal status in not set in stone and is still under discussion worldwide. As mentioned above, in September 2020 the EU Commission released some plans for EU-wide regulations for cryptocurrencies. These plans are still in a preliminary state and subject to change.

What is interesting, is the fact that this report separates stable coin from regular cryptocurrencies and divides them into two categories. The "Asset-referenced token" which is a type of crypto asset that its main purpose is to be used as a means of transaction. It manages to maintain a stable value by referencing multiple FIAT currencies, or one or more commodities, or one or more crypto assets, or a combination. The second category is named "Electronic money token" and has the same usage as the "Asset-referenced token." Where it differs is that it is denominated against a single FIAT currency. The second category is where USDT resides according to its whitepaper.

Environment:

Despite being created on POW blockchain due to its own consensus mechanisms it does not have environmental effects similar to BTC or ETH. Tether is able to generate and burn tokens without significant environmental cost since the only requirement is to have reserves equal or greater than the number of USDTs in circulation. The company has no environmental policy and focuses purely on the economics system *(Tether, 2016)*.

Chapter 5 : Discussion

In this chapter a dive into the results and their importance is attempted. This is mostly focused on the consensus mechanisms as they are the "heart and soul" of every cryptocurrency, and they define all its procedures. Additionally, the PESTLE results are discussed for two different points of view. One focused on each cryptocurrency and one focused in their effects. Finally, a calculation for the electricity demands between BTC and ADA is shown in order to make clear what created the vast resource difference between a POW and POS cryptocurrency.

5.1 Consensus Mechanisms and Sustainability

With the aim of answering the research sub-questions a deep dive into the mechanisms and internal workings of their cryptocurrencies was necessary. The first step was identifying the consensus mechanisms that are being used and their sustainability. These mechanisms' primary objectives are to validate transactions, protect the blockchain from potential damaging actors and produce new coins or tokens.

Bitcoin (BTC), who was the first cryptocurrency, use the consensus mechanism called Proof of Work (POW). The same mechanism is used by another crypto that is researched, Ethereum (ETH). The POW concept uses computing power in order to validate transactions and mine new coins or tokens. To ensure the systems safety, this computing power is used to solve inconsistent puzzles with increasing difficulty that rewards the miner who solves it first. Miners compete with each other and as more and more participate in such activities the energy consumed is increased as well. While at first glance this mechanism might seem unsustainable due to the large electricity demands a counter case can be argued. Since the miners want to produce cryptocurrencies with lower costs it is only natural to turn their attention to the cheapest type of electricity. In many cases renewables can fit this role. This can potentially create crypto hubs and promote renewables. Still, it does not solve the issue that this energy could be repurposed to more immediate needs and that this remains a theory up until now. Where the POW really shines is in the security department. The main danger these systems face is the so called "51% attack". It occurs when more than 50% of the computed power is controlled by a single entity or a group of entities that lobby and they decide which transactions to confirm and which to reject. Due to the fact that constant and high verification cost this danger is mitigated significantly at least for most dominant players in the market such as BTC and ETH *(Tradingview.com, 2021)*. Although the interconnections work almost flawlessly this type of system has some sore points such as the low number of transactions per second, high transaction costs and low adaptive capabilities. High security can be a double-edges sword in this case as reaching consensus for changes in how a cryptocurrency operates can be staggeringly slow procedure which is mostly evident with BTC.

On the other side of the spectrum Proof of Concept (POS) exists, ADA uses POS. In this case the participation rules differs and instead of computing power and initial amount of said cryptocurrency is used. This amount is being staked and usually locked in a certain period of time, with rewards being distributed accordingly in the end of the process. Due to the high entry costs many users form groups called stake pools something that is not present is POW mechanism. It does have a noticeable advantage over POW but some noticeable disadvantages as well. First and foremost, the difference in energy usage is crucial to mention. POS cryptocurrencies have less energy requirements compared to a POW crypto. Additionally, transaction speeds are higher, costs are lower and allows prominent levels of adaptability. Overall, is seems like a more efficient system. It does have its drawbacks that have to be mentioned as well. Due to the fact that a lot of the POS cryptocurrencies are pre-mined higher levels of centralization exist and alongside the high entry costs go against the DeFi system which is one the main selling points of any cryptocurrency. Outside of these two categories a lot of other mechanisms exist but the focus is given in Proof of Reserves (POR) and Proof of Burn (POB). Both mechanisms are used extensively from Tether (USDT), but POB can theoretically be used in any cryptocurrency. From a technical point of view all these mechanisms are sustainable with the only requirement being to have entities willing to invest on the production of a cryptocurrency. Otherwise, the systems are secure, but the adaptability factor varies depending on the difficulty of reaching a consensus and allowing upgrades. The larger and more decentralized a cryptocurrency is the tougher is to reach consensus but on the other hand it is also harder for a 51% attack (section 4.2.1) to be successful.

For an environmental standpoint, one discussion point put forward for a deeper analysis is whether cryptocurrencies that use POW and thus mining as their means of production are less sustainable than currencies that used other consensus mechanisms such as POW or POR. The knowledge baseline to bring this point to the reader's attention lies on the need for specialized hardware and energy consumption which constitutes POW cryptocurrencies. This proved to be very resource demanding, and this is evident by the fact that other consensus mechanisms only require capital and lesser amounts of electricity to operate. In this case BTC and ETH belong in the first category and ADA and USDT in the second one. Even further, as mentioned above the Ethereum network is in the process of changing its system to use POS mechanisms instead of POW. On the other side BTC uses its vast energy consumption and increasing difficulty to generate value. Something that is not environmentally sustainable as the electricity and hardware requirements will only increase in the future. Out of the four cryptocurrencies BTC is the only one that seems to prefer this route.

5.2 PESTLE Results

In this part the PESTLE results are discussed from two different point of views. Firstly, a discussion about each currency and how they fare with each other over. And secondly, from the perspective of the main question

5.2.1 Cryptocurrency Comparison

When the four dominant cryptocurrencies are compared through PESTLE the main discussion points are as following:

Bitcoin (BTC): Bitcoin, being the first cryptocurrency created has successfully created a legacy and continues to be the centerpiece of this ecosystem. Its market control is unquestionable with over 40% control at any point of its life. It is also the first cryptocurrency to be accepted as legal tender by countries such as El Salvador and companies such as Tesla. Despite this, BTC has some core issues and the lack of consensus between the miners is at the center of it. While other cryptocurrencies as seen below, constantly develop and innovate solutions BTC remain stagnant and fails to address this energy consumption problems. If the situation remains unchanged its sustainability is questionable as more projects outperforms BTC technologically. One should not disregard though that this type of process is one of the main reasons that provide BTC with its value.

Ethereum (ETH): Ethereum the second largest cryptocurrency second only to BTC is biggest innovator in the field with breakthrough such as the Byzantium Fork and the introduction of smart contracts. Although it might not have achieved the international recognition BTC has it is highly regarded amongst the cryptocurrency circles for its contribution in blockchain technology. Currently, it has the largest number of developers working on it and the project ETH 2.0 is underway. This project aims to transition ETH from a POW protocol to POS. The main reasons for this transition are the reduction of greenhouse gas emissions, lower transactions costs, faster transaction speed and larger adoption as a usable currency.

Cardano (ADA): Cardano and Ethereum share a lot of history due its founder also being one of the Ethereum founders as well. Direct competitors since the start, Cardano lunched its token named ADA under a POS protocol. This has allowed ADA to have low-cost transactions and a high potential ceiling for TPS. Although the network now operates under 7 TPS it has been tested, albeit in a controlled environment, and achieved over 250 TPS. It has also achieved cooperation with the education ministries of Georgia and Ethiopia something which provides the network with recognition and legitimacy. At the same time as ETH tries to move into a POS environment, Cardano tries to implement smart contracts into the system. It must be noted that two of the most innovative crypto projects both move towards the direction of POS protocols combined with smart contracts.

Tether (USDT): Tether is a unique category of cryptocurrency with its pegged price towards US dollar. It has achieved to become the most used and highly valued stable coin. Due to its POR protocol has a low energy demanding, like POS. Legally though, Tether has found itself into legal battle with the New York city attorney and continually refused to be audited. It has also been involved into a few scandals with the most

prominent being the involvement the company had with Bitfinex, a crypto exchange company. Although technologically provides an interesting solution for the mitigation of the volatility in the crypto market its practices raise questions.

5.2.2 Evaluating the Effects

When focusing on the main question of this research and the results of PESTLE analysis (third research sub-question) we can say that:

Environmental: BTC and ETH are the largest two polluters in crypto space. ADA and USDT have exceptionally low amounts of emissions. With Ethereum's transition to POS it expected that a 99,5% reduction emission will occur combined with other improvements such as network speed and transaction costs. With this complete ETH will be closer to ADA and USDT in the energy consumption department. Use of renewables is another point of interest but the results vary depending on the institution that performed the research and thus clear results are not present. Cryptos that do not use POW and mining (ADA and USDT) have no requirement for expensive and scarce hardware equipment (BTC and ETH).

Political: Out of the four only BTC has been accepted at legal tender by a government. This happened in the first quarter in El Salvador and other countries consider this option. Another cryptocurrency that has some form of official recognition is ADA through its deals with the ministries of education of Georgia and Ethiopia. ETH continues to function mostly on a private level and no major movements from public institutions have happened. In opposite side of the spectrum lies USDT which is in an active legal battle with US institutions due to the lack of transparency.

Social: Bitcoin remains the only easily recognizable cryptocurrency up to date to the public. The other 3 (ETH, ADA, USDT) although they occupy a sizable portion of the markets have failed until now to become widespread and known to people that do not deal with cryptocurrencies and blockchain technology regularly. Even amongst people with knowledge of blockchain technology ADA and USDT are relatively unknown.

Overall, all currencies that were researched have potential and future in the crypto ecosystem but for varied reasons. BTC as a store of value and a currency that is increasingly difficult to obtain as the mining amount becomes less and competition rises. ADA and ETH through their combination of POS, smart contracts, and the innovation their bring to the field. And USDT can remain the dominant stable coin if it addresses the concerns about its reserves and lack of transparency.

5.3 Electricity Consumption Calculation

In this part a simple model is formulated to calculate the electricity consumption of BTC which uses POW against ADA which uses POS. This attempt aims to contribute to this type of estimations that can shed some clarity on the energy (electricity) consumption of cryptocurrencies. The model has several limitations which are:

- The model takes only into account the hash power for determining the electricity cost for BTC. This does not include secondary costs and results in a very conservative estimate.
-
- The hash power and electivity demand (watts) of some ASIC unit for BTC mining is an estimate calculated by comparing the models from *Amazon.com* and *BuyBitcoinWorldwide.com*. This is not an accurate representation since these machines are the most efficient and a lot of miners still use GPU or CPU units. It most likely, a best-case scenario for Bitcoin.

- Some parameters such as the nodes requirement for each ADA stake pool are an assumption. When a parameter is assumed, it is clearly mentioned.

1) The calculation for Bitcoin mining in TWh/year (data on 7 June 2021 from) is as follows:

In the tables below a table presenting the BTC miners that are used for this calculation and a secondary table showing the units that are used in the calculation.

Table 8 *: Bitcoin miners TH/s & Watts (source)*

Model	Tera Hash per second (TH/s)	Watts
AvalonMiner 1246	90	3420
AntMiner S19	95	3200
AntMiner S19 Pro	110	3250
AntMiner s9j	14	1250
Aladdin L2	30	2400

***Table 9** : Measurement Units (source)*

Units	
Kilo	1E+03
Mega	1E+06
Giga	1E+09
Tera	1E+12
Peta	1E+15
Exa	1E+18

Through the calculation of the average Tera hash per second (**67,8 TH/s**) and the average Watts (**2704 Average Watts**) the average **watt per TH/s** is determined to be **39,88**. This is **3.988E-11 Average Watts/Hash/s**.

On 7 June 2021, the Bitcoin network used **97,93 EH/s** *(bitinfocharts.com, 2021)* which is **9,793E+19 Hash/s**. The multiplication of Average Watts/Hash/s and the total network hash rate which is **9.793E+19 Hash/s** provides the total power consumption: **3,91E+9 Watts**. Each year has **8760 hours** thus multiplying these two numbers shows the Watt hours per year: **3,42E+13 Wh/year** which equals **34,21 TWh/year**.

2) The calculation for ADA staking in TWh/year on 7 June 2021 is as follows:

ADA does not need mining equipment to produce new tokens. Instead, the minting process occurs through the stake pools. For the shake of this model, I assume each stake pool requires **3 nodes** to operate. Each node only consumes the energy required to have it connected to an outlet. In this case this is 30 Watt per hour.

On 7 June 2021 according to *adapools.org (2021)* the number of stake pools that were operational was **1018**. With that in mind, the total power consumption is the multiplication of the operational nodes, number of nodes required for a stake pool to operate and the Watt per hour. This equals **91.620 Watts**. Following the same logic as above, each year has 8760 hours (about 12 months) which makes the total energy consumption in a year equal to **802.591.200 Wh/year** which equals to **0,000802 TWh/year**.

Even when considering a best-case scenario for BTC, according to the numbers here above, its annual energy consumption equals to **34,21 TWh/year** while ADA in an average estimation has only **0,000802 TWh/year**. In this case ADA is **42655 time**s for energy efficient than BTC. This result can be considered as an indicator of the differences between Proof of Work cryptocurrencies and Proof of stake, but more evidence is needed to make sure a fair comparison is done. But the intention of showing these values is to show, to some extent, how BTC has some advantages by ignoring

secondary and hardware costs and only taking in mind the most efficient ASIC miners it is thousands of times less energy consuming than ADA.

Again, it important to note that this is a best-case scenario for BTC and an average scenario for ADA. In reality, the difference is probably larger and BTC energy needs are closer to the examples of section 4.3.1. This simple calculation is part of this research simply to show a bit more elaborately to the average reader the difference between POW and other consensus mechanisms. Hopefully in the future accurate measurements about the energy consumption of POW cryptocurrencies can be calculated including the secondary costs such as requirements for creating an ASIC unit.

Chapter 6 : Conclusions and Recommendations

This chapter includes the conclusions built on the results of this research, recommendations of this work in relation to the long-term sustainability of cryptocurrencies. Few suggestions about follow up research points that can be examined in the future. Each sub-question is discussed in order with the goal of providing an answer to the main question which is: What are the environmental, political, social effects of the four cryptocurrencies (BTC, ETH, ADA, USDT) and are they sustainable in the long-term?

6.1 Conclusions

To provide an integrative answer and conclusion to the main question, firstly some of the highlighted answers per each of the three sub questions were re-called here as follows:

Sub question 1: In what ways do consensus mechanisms affect the long-term sustainability (as described by SMT) of these cryptocurrencies (BTC, ETH, ADA, USDT)?

According to the literature review a variety of consensus mechanisms exist and while all have the same final purpose (the production of a cryptocurrency unit) the way this is achieved can vary.

Bitcoin and Ethereum use the Proof of Work mechanism while Cardano and Tether use Proof of Stake and Proof of Reserves, respectively.

While all the consensus mechanisms cover the basis of SMT (Interconnections, Feedback loops, Adaptive capacity, Self-organization) the degree of success varies. POW is more robust and secure compared to other mechanism such POS or POR due to the difficulty to reach consensus and the large costs required to gain majority. This inability to reach consensus has some negative effects as well as it hurts the adaptability and self-organization of POW. On the other side, POS and POR have the exact opposite image. Despite these variations all mechanisms are adequate according to SMT.

The long-term sustainability for POW can be questioned simply due to the large energy requirements. This is one of the reasons ETH is transitioning its internal structure to operate under POS.

Sub question 2: Following life cycle thinking, what are the environmental impacts of 'mining' and 'minting' of each currency (BTC, ETH, ADA, USDT)?

The main unit of comparison was TWh as shown in most prominently in the calculation example (5.3) and the resources requirement (4.3.1) sections. Secondary costs do exists but their calculations is not part of this research.

The requirements for producing a cryptocurrency are directly connected to the type of consensus mechanism. POW requires the mining process to take place which requires hardware and substantial amounts of electricity to operate. Opposite to that, consensus mechanisms that require only minting have significantly less resources since only capital is required to enter.

The hardware requirements for mining can be CPUs, GPUs, or ASIC units. Due to their decentralized nature calculating exactly the materials and the exact electricity requirements are exceedingly difficult to pinpoint with accuracy.

Despite the lack of accurate measurements (data), it is predictable in a way (as shown in section 5.3) that POS and POR cryptocurrencies have negligible energy requirements against POW cryptocurrencies.

Their usage on the other hand, while affected by the consensus mechanism and production process, is not defined by those. The ecosystem is still at an exploratory state and tries to determine which methods pair better.

The end of life is another point of interest as it is different than most of the products. Due to the blockchain system the data cannot be simply deleted but only locked or forgotten in a way that cannot be accessed anymore.

Overall, in line with my findings, it can be said that mining is affecting the environment in a negative way while minting can be considered a greener choice.

Sub question 3: Do these products (BTC, ETH, ADA, USDT) address the key requirements for sustainability and how do they compare with each other (using the PESTLE analysis)?

Through literature and PESTLE analysis it is clear that these cryptocurrencies cover the requirements for sustainability according to SMT but to a varying degree. When it comes to environmental sustainability though, Proof of Work cryptocurrencies raise concerns for their electricity consumption and its potential future effects. This is a point that must be addressed and an issue the other cryptocurrencies manage to avoid.

When compared with each other the strong points and weaknesses of each cryptocurrency become evident.

To the best knowledge of the researcher currently, BTC is the most polluting cryptocurrency with no plans to tackle this issue in the future. Additionally, the lack of consensus amongst the miners makes it difficult and close to impossible to reach a decision. This has a positive side though, as this issue makes it the most secure of the four cryptocurrencies. Another shortcoming of BTC is the lack of scalability which makes it slower than its peers.

Despite these shortcomings BTC remains by far most influential cryptocurrency and every other crypto follows its market moves. The market domination seems to remain above 35% at any point of its life and even reaching 80% through some time periods.

ETH follows BTC closely and it is the second most polluting and dominant cryptocurrency. Where it differs is in the innovation department. Together with Cardano they are some of the most active and fast developing blockchains. ETH also tries to tackle the environmental effects by switching to POS protocol.

Following ETH, come ADA. While significantly small in value it is a direct competitor of ETH in the innovation department. Both cryptos try to combine smart contract and POS in their network. Although, it also one of the most active and green cryptocurrencies it remains unknown outside of the blockchain ecosystem. A problem which all cryptocurrencies, except BTC, have to deal with.

Trying to integrate the findings to respond the Main Question (What are the environmental, political, social effects of the four cryptocurrencies (BTC, ETH, ADA, USDT) and are they sustainable in the long-term?) This work enables the researcher to conclude that the leader in social and political effects in the crypto world is Bitcoin. The way society perceives cryptocurrencies is tied to Bitcoin and its usage. Something that is prevalent in the academic world as well. This leads to misconceptions and to a lack of acceptance of other cryptocurrencies and their technology.

As far as the environmental impact of each cryptocurrency a definite order as to which one is less environmentally damaging cannot be given due to the lack of precise data. What can be identified though is which type of mechanisms can be associated to polluting mechanisms. Proof of Work is the main culprit in this case as all the other discussed mechanisms do not require vast amounts of hardware or electricity. With this information it is safe to assume that Bitcoin and Ethereum in its current form are less sustainable than ADA and Tether.

Long-term sustainability is a concern only for cryptocurrencies who use Proof of Work and ways to reduce its negative impacts on the environment must be further explored to ensure balance in a time where global warming effects become more and more prevalent.

6.2 Recommendations for Further Research

This research was able to give an answer as to what are the effects of said cryptocurrencies and if they can become long term sustainable. In hindsight for the social effects a survey approach might have more appropriate and allow more detailed results about the way people perceive cryptocurrencies and blockchain. Due to the time and scope limitations of this thesis a plethora of opportunities arise for further research.

For example, the need for accurate calculation of the primary and secondary costs of cryptocurrencies that use Proof of Work -and not only- has arisen in multiple places throughout the document. Moreover, an in-depth analysis as to why both Ethereum and Cardano try to move towards a POS plus smart contracts direction and what effects this might have in the crypto ecosystem is something worth of notice. Additionally, possible solutions for the mitigation of the energy issues cryptocurrencies have been another point of interest.

Due to the time constraints and complexity of the issue the life cycle thinking I applied limited, mainly done conceptually, hence more research can be done to determine the exact origins of the materials used in the creation of GPUs, CPUs, ASICs units and dive deeper into their potential uses and recycling opportunities. Due to the rapid evolution of blockchain technology it was close to impossible to cover all the innovations, technological and economic actions that occur on a daily basis and this dynamic process always provides opportunities for further research.

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Appendix 1 – Interview Consent Form

Consent form used for the interviews:

CONSENT FORM FOR RESEARCH STUDY INTERVIEW
Comparative study on the environmental, political, social effects and long-term sustainability of Bitcoin, Ethereum, Tether and Cardano cryptocurrencies

	Yes	No
- I, Florian Helfrich, voluntary agree to participate in this research study interview.	√	☐
- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any number of questions.	√	☐
- I understand that I can withdraw permission to use data from my interview after it. In this case the material will be deleted, and the data will not be used for the research.	√	☐
- I have had the purpose and goal of the study explained to me and I have had the opportunity to ask questions about the study.	√	☐
- I agree to my interview being audio-video-recorded. The video will be stored safely and deleted after the completion of the transcript.	√	☐
- I understand that all information I provide for this study will be treated confidentially.	√	☐
- I understand that in any report on the result of this research my identity will remain anonymous if preferred to be so. This will be done by not explicitly mentioning my name and disguising any details of my interview which may reveal my identity or the identity of people I speak about.	√	☐
- I understand that I am entitled to access the information I have provided after the interview.	√	☐
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.	√	☐

Here you can find the names of the people involved in this research who guarantee the agreed use of this consent and the answer provided during the interview.

Researchers:	**Project Supervisor**:	**Participant**:
1. Evangelos Stamoulis	1. Dr. Laura Franco-Garcia	F. Helfrich
	2. Dr. Victoria Daskalova	*Signature of participant*
		Date: 29.06.2021

Appendix 2 - Questionnaires

Questionnaire provided before the interview:

Questionnaire

Dear Participant,

First and foremost, I would like to express again my gratitude for your willingness to participate in my research project. As mentioned in my previous e-mail, interviews with key respondents are a crucial part of my thesis for the Master's in environmental and energy management (MEEM) of the University of Twente (UT).
The primary goal for this project is the examination and comparison of four different cryptocurrencies in terms of environmental, social, political and long-term sustainability. The four cryptocurrencies are: Bitcoin, Ethereum, Tether and Cardano's native token ADA. They have been chosen as they have different consensus mechanisms, functionalities and, purpose from each other. The semi-structured questionnaire to be used during the interviews is displayed below. The questions enlisted are illustrative to the main points of the research. It is possible that additional questions might be asked to gather more detailed information. The duration of the interview is estimated to last 45 minutes. As part of my University's ethical procedure to gather data I kindly ask you to answer the questions of the Consent form, which attached to this letter. From that form I need to know the level of confidentiality you are comfortable with, for the information that you will generously share with me. I will appreciate if you can answer the questions, sign it up and send it to me via e-mail.
If you have any question in regard to the interview, the research topic or anything else please do not hesitate to contact me. I will answer to the best of my abilities before the interview.

Researcher:
Evangelos Stamoulis
Student of Student of Master Environmental &Energy Management (MEEM) – CSTM Governance and Technology for Sustainability at the Behavioral Management and Social sciences faculty

First set of Questions:

1) What is your experience with blockchain technology and are you familiar with the four cryptocurrencies' (Bitcoin, Ethereum, Tether, Cardano) environmental impact ?

2) Bitcoin is the oldest and largest culprit when it comes to CO2 emissions. How this issue can be tackled through each stage of its life cycle (resource acquisition, manufacturing, distribution, use and end of life)? , i.e.

3) Ethereum is undergoing a transition from 'Proof of Work' to 'Proof of stake' mechanisms. In what ways is this change going to affect the interconnections (balance between self-preservation and responsibilities) and the adaptive capacity of Ethereum?

4) Cardano is based on the Ethereum blockchain and is using 'Proof of stake' and one of its
main goals is "to provide a more balanced and sustainable ecosystem" according to its founder Charles Hoskinson. How close is ADA to this goal in your opinion?

5) Tether is stable-coin for the US dollar and concerns about manipulation and lack of transparency circulate it while at the same time remains the most used stable-coin. In your opinion if those concerns prove true, is the whole cryptocurrency market at risk?

6) Crypto market is still in the process of mass adaptation. Do you think its current state can support mass adaptation or changes have to made? And if changes are required, what are your recommendations?

7) Regarding the political and legal aspect of cryptocurrencies, what steps should the regulators and governmental institutions take to ensure a sustainable future in your opinion?

8) Are you worried that future regulations would compromise the unique future blockchain products have such as transparency, security and efficiency?

9) Where do you see these four cryptocurrencies and blockchain technology overall in the next decade?

Second set of Questions:

1) What is your experience with blockchain technology and are you familiar with the four cryptocurrencies' (Bitcoin, Ethereum, Tether, Cardano) environmental impact?

2) Bitcoin is the largest culprit when it comes to CO2 emissions in the crypto world. How this issue can be tackled through each stage of its life cycle (resource acquisition, manufacturing, distribution, use and end of life)?

3) "Proof of work" is considered by many the consensus mechanism with the most negative environmental effects. How much truth do you believe this claim has?

4) What are the advantages "proof of work" offers against "proof of stake" on the social and political level in your opinion?

5) Crypto market is still in the process of mass adoption. Do you think its current state can support mass adoption or changes have to made? And if changes are required, what are your recommendations?

6) Regarding the political and legal aspect of cryptocurrencies, what steps should the regulators and governmental institutions take to ensure a sustainable future in your opinion?

7) Are you worried that future regulations would compromise the unique future blockchain products have such as transparency, security and efficiency?

8) Where do you see these four cryptocurrencies and blockchain technology overall in the next decade?

Appendix 3 - Interview 1 Transcript

Date: 21 July 2021

Type: Online Interview

Duration: 24 minutes 46 seconds

Interviewer: Evan Stamoulis

Interviewed: Anonymous

Notes: This interviewee requested anonymity for personal reasons and is employed in the banking sector. The interviewee is referred to as Anon in the transcript.

Start of recording

Anon: Okay, I think I started the recording. Should be okay now

Evan: Yes! Perfect, thank you. Let's start then. First things first can you tell me a few stuff about your background and how you involved with cryptos?

Anon: Yeah okay.. So, I have like around 5 years of experience in the banking sector.. always been in the same bank, didn't change but my interest in crypto is strictly personal. Around uhh maybe 2 years ago? I found out about all these stuff.. blockchain, crypto and you know, got interested into that.

Evan: Aha I see… and if I may add to the question, do you know these four cryptocurrencies I research about?

Anon: Well, of course I heard about Bitcoin and Ethereum these are like the key players you know, mostly Bitcoin I would say. I have also used Tether and heard about uhh.. Cardano. I am not familiar with it though, only heard the name and a few stuff about the owner.

Evan: Yeah, that's great, most people are only familiar with Bitcoin so I'm happy talking to someone who has heard all four at least.

Anon: Yeah, like of course most people only know Bitcoin.. it is by far the most dominant like hearing that Bitcoin equals crypto does not surprise me anymore hahah

Evan: Hahah yeah this very true.. lets continue..

Anon: Sure..

Evan: With the next question which is uhmm can you tell me a few words about what you know of these four cryptos?

Anon: Well, as I said Bitcoin is by far the most dominant, talking in market terms of course, followed by Ethereum.. These two are the uhh.. you know I think they are here to stay for good but of course there are issues with the energy consumption for example, especially for bitcoin is getting high and there were some recent news.. don't know if you hae heard about the comments Elon Musk made regarding Bitcoin?

Evan: Yeah I heard about it being too energy demanding..

Anon: Yes this.. so you know this is an issue and for me as an investor I might care for uhh you know improving my uhh.. position in the market and these comments affect me. So, like uhh.. everyone should be careful of their surroundings and what news come out…

Evan: I do agree with that… what about Tether and Cardano?

Anon: Well, Tether is a stable coin and is used if still want to have dollar but on the blockchain. I find it pretty cool you know its still dollar but at the same time it isn't but right now I am thinking of some alternatives because I saw the news about some audit issues..

Evan: Hahah that is actually part of my research as well, yeah like Tether is uhm.. how to say it, pretty sketchy when it comes to audits and transparency.

Anon: Yeah that is why alternatives exist so we can change and be secure.. Anyhow, as for Cardano very few stuff.. only that the owner used to work in Ethereum and then left, haven't looked into it to be honest, from uhm.. an investing standpoint at least.

Evan: Yeah I see that's totally fine.. You know my research is mostly about the environmental effects of the different mechanisms in the blockchain like proof of work and proof of stake… You already said Bitcoin has some energy issues can you elaborate a bit on that?

Anon: Yeah of course, I said Bitcoin has environmental concern but at the same time it by far the largest part of the crypto market so that is to be expected and all the uhm.. spotlight goes there. But I think the main issue with energy in crypto is, as you said, the consensus mechanisms behind each crypto. I think it is proven than proof of work is more polluting due to the electricity it needs to operate. To tell you the truth I am not very familiar with the technicalities but like staking I know for example uses way less resources. And that is very interesting because as people focus on the environment and its protection it is very possible that will start rejecting energy heavy things and that applies for crypto as well. It is important to see how this develops because Bitcoin needs to find a solution to that from one side but on the other side, personally, I believe people will still invest in it despite the environmental concerns..

Evan: I see you are focusing a lot about the investing opportunities on the sector and I think that is accurate since.. well, you work in the banking sector. So, tell me how do banks react to crypto? Do they see it as a threat or maybe an opportunity?

Anon: Hmm very interesting question.. I would say yes and no… Okay first, we need to separate blockchain from cryptos… As far as blockchain as a technology I think it has a lot of potential in the sector because of the security it provides and I can see it being used in other sectors as well that need umm… you know, good libraries and umm documentation. Still, it is relatively unknown and just now started to be explored. As far as cryptocurrencies go… that's a different story… Most banking institutions consider them a problem and uhm.. for good reason. When you talk about decentralization then that hurts banks the most which are centralized. That is the reason I wanted to remain anonymous, you understand…

Evan: Yes certainly and to make sure, Ill send you a copy before to make sure its okay with you.

Anon: Yeah thank you.. anyway, as I was saying banks feed threatened from one side but I see and some others as well an opportunity for the banking system. Most people buy and sell cryptos through exchange platforms which arguably are centralized, so despite decentralization talk, crypto market is still centralized up to a degree and this is where the traditional banking sector can find a good opportunity. Of course though, the financial sector and humans in general is very risk averting. You know, they don't want to risk going into such a volatile market with their. At least most of them… this notion has started to change the last years but it still remains an issue. Without proper regulations this will remain an issue and in my opinion if cryptos want to go mainstream they have to be regulated… when this happens then the traditional system might warm up a bit more…

Evan: I really like you mentioned regulations because this is my next question. You mention regulations but isn't this against the idea of what crypto represents which is decentralization and freedom? How can this affect them long term?

Anon: Huh important question to make with a simple answer.. I think it fall under human nature again of risk aversion and also greed. When its about money usually ideals go "bye bye", and people just focus on profit. We are talking about decentralization but how true is that? As I mentioned before trading mostly happens in centralized exchanges so most people don't care about that. Of course there are some hardcore supporters of it but they are a minority. What the majority care is about profit and security. Regulations are going to happen either we want it or not. And they are needed, people cannot go around wasting their lifesaving into dangerous investments…

Evan: But doesn't this go against freedom of using my money as I want?

Anon: Kinda, but let's be real, most people do not want and are not capable of being their own bank. They simple lack knowledge and time. Here in (bank's name) we have a lot of complaints from people who withdrew their money and lost them in the crypto market. Some even said we didn't warn them! You see, regulations are bound to come and deeply needed… Now the market like the wild west which benefits experienced players and makes newcomers in danger.

Evan: I see, and understand the points you are making.. I don't know if you have heard that Korea and Japan has limited trade for some cryptos. I this the right way to implement regulations?

I haven't heard about it to be honest.. can you tell me a bit more about it?

Evan: Yeah so they have limited trade in some uhm.. sorry for the term but shitcoins like Doge and some others..

Anon: Oh don't worry that is the correct term hahah.. Okay so I see.. Yeah then I agree this is a nice approach to protect the costumer and I think it is a step in right direction. I would argue that till now all cryptos are speculative.. some like Ethereum are doing some moves but it still needs more. When you add that 99% of them have no use cases and are pump and dumb schemes.. you know the term right?

Evan: Yeah yeah..

Anon:…okay so, of course the trade of these should be limited and that way limit the risk. I know a lot of people might not like it because it limits their potential to gain a lot of money but it is necessary and it also necessary for the crypto market to become less volatile… now its too much to be taken seriously.

Evan: I assume you are talking about adoption but then what about El Salvador accepting Bitcoin as a legal tender? Bitcoin is still very volatile but big institutions and governments seems to favor it.

Anon: Well yes that is good for larger adoption but again its one of the same. Bitcoin is the least volatile crypto and also has the reputation to back it up. This alongside the fact that uhm.. it can be considered a store of value like gold increases its chances.. Ah excuse I need to pick this up..

Phone call interrupts the interview (7min)

Anon: Sorry about this but I do not hae much time. Is it a problem if we can cut this interview a bit short?

Evan: Uhh.. no its okay…

Anon: Please ask me 1 more question and then I have to go.

Evan: Okay really fast then where do you see the 4 cryptocurrencies and blockchain as a whole in the future? Let us say about 10 years?

Anon: Hmm that is quite difficult to say because I don't know all of them so much.. I do believe Bitcoin will still exist but for the others I can make a guess… What I can say is that I like to compare the blockchain technology with the internet when it started. Many people called it useless then but I think it has a lot of potential but changes need to made. I cannot even imagine the form blockchain and cryptos will have in 10 years.. They still will cenrtainly be around but what crypto and in what form I have idea you know. And I say Bitcoin will still be around due to its name and history but it might not be the dominant player anymore… now that I think about it Ethereum has some good chances if it addresses successfully its inflation issues as for the others I cannot say.

Evan: Okay I see.. Well, thank you very much.. despite this interview being a bit short I think I got a lot of interesting information and thank you again.

Anon: Oh no I have to apologize for cutting it short but sometimes schedules change suddenly. Anyway, thank you very much it was a very interesting discussion and please do send me a copy of the thesis… Okay I stop the video now.

End of recording

Appendix 4 - Interview 2 Transcript

Date: 29 July 2021

Type: Online Interview

Duration: 50 minutes 50 seconds

Interviewer: Evan Stamoulis

Interviewed: Florian Helfrich

Notes: -

Start of recording

Evan: So shall we start.. You mentioned a few stuff about your background especially focusing on Bitcoin, so I would like to ask you if you know anything about the other 3 currencies.

Florian: Yeah of course I have heard of Ethereum. I did hear about.. Let me check.. About Cardano or Theta and I have to say I mean... I really focused on the Bitcoin network in my thesis. Ethereum is super interesting because it has way more application cases. Eh.. But in the academic literature or in the public community as I would say Bitcoin the one most dominant one and the most referenced, of course. Also of course the most criticized because its currently always in the news.. is shifting drastically in shorts amount of time.. But I have to admit I didn't hear about the last 2.

Evan: Ok, so I can just give you a small background of them..

Florian: Yeah!

Evan: Just so you know about these and what we are talking about. So.. Ehm.. My idea was to choose the biggest cryptocurrencies that exist right now in the market.. Not only in market terms about also in what technology they are pushing. Bitcoin is proof of work the biggest one as you said, most publications and stuff..

Florian: Yeah.

Evan: Ethereum is number 2 most innovation doing a lot of technology stuff in the background.. Very interesting project as you mentioned as well. Tether is a stable coin.. Are you familiar with the term?

Florian: Yup.

Evan: It is the largest one.. It has a lot of criticism as well, especially due to its backing system.. How the USTD dollars are transferred to USD dollars and stuff like that. And Cardano is.. Ehm right now the largest cryptocurrency that uses proof of stake. Which

probably some.. I don't know if you heard about the transition Ethereum is going to proof of stake...

Florian: Yeah.. I mean that's already for a couple of years right.. Like..

Evan: Yeah.. And its still far away but... yeah this is the process.. That they are trying to do. Ok.. Bitcoin is by far the largest culprit when it come to CO2 emissions, in the crypto market of course. What can you tell me about this issue.

Florian: You mean how blockchain is set up?

Evan: More general in the terms of... why is Bitcoin so polluting compared to other cryptocurrencies?

Florian: Okay so 9in the environmental aspect. Yeah.. Yeah.. I thing this is a very huge question if you are talking about cryptocurrency systems in general. And I would say the most difficult challenge to master if you want to establish Bitcoin long term is the proof of work mechanism. For me I understand proof of work mechanism really as drive up hardware costs, hardware usage as well as energy consumption.. Hugely.. And umm I assume you are very familiar with the mining processes and for me one of the social aspect that is connected to the environmental aspect is that if you say okay we have some miners where people come to bundle their energy and that in turn increases the spend of the other mining and other individual miners of course. You can see mining is mostly established in countries where energy is not very green and cheap to use.. So of course local energy price is directly connected to pollution for me. Umm.. and I see this very critical because.. I mean in theory you can have proof of work without demands energy consumption right?

Evan: Yeah.

Florian: But what us driven like the energy consumption is driven up well of course, people want to make a profit. So if my neighbor invests on a better mining rig then I can either yeah I am going to take the loss in the long term or also I'm gonna build up more hardware and use more energy of course... so that is a really difficult challenge and yeah for now from the technical side, I don't see any solutions in that because.. Oh well, it's just upwards spiral. In the theory you can go back, if everyone agreed to reduce their hardware then the algorithmic difficulty with the hashes will be adjusted. So in theory it wouldn't be a problem but... yeah...

Evan: A consensus like this is practically impossible to achieve because the moment someone steps down someone else is going to take his place.

Florian: Exactly, umm so.. Umm please go ahead.

Evan: Sorry I was just going to... as you said it is directly linked to economic and social reasons.. What about regulations? The political side of things?

Florian: Yeah this is very interesting to me as well for the concept of he general idea... if you want to start from the whitepaper from Nakamoto of course, umm to become decentralized and not governed by a central authority right..? So if we are talking about regulations I find it very umm difficult to talk about regulations if you are not familiar with the concept behind and that is what I see from governments trying to tackle this

issue... So I don't know I just read last week that European central bank in now trying to develop a digital Euro which is not blockchain at all so they still call it cryptocurrency but I find it very funny because directly shows that they have no clue about blockchain technology at all if they just try to make digital money that is still managed from a central authority.. For me that is not decentralized.

Evan: People tend to umm.. When they thing of cryptocurrencies they just say digital money.

Florian: Exactly, yeah I think this is a very important distinction to make especially if you talk to uniformed audience.. So always when I try to explain my research I always try to provide a bit of historical background on the theoretical potential it has because it is just very difficult to grasp if you have a centralized infrastructure of financial systems for example and revolutionaries suddenly on something that is upholded by a network of stakeholders or individuals.. Umm yeah..

Evan: So can I jump back for a second in... the legalities of things because some countries like Japan and Korea they have restricted the trading of some specific crypto with excuse they want to protect the investors.. And that is a valid concern because as you said they are uniformed and people don't know much about it and they are in danger of losing their money..

Florian: Yeah.

Evan: From one side we have this decentralization and from the other side we have some regulations umm... that help some people to protect themselves.. Is there a balance there? What is your opinion on this process?

Florian: Very very important question because as soon as centralized regulators get involved there are some conflicts arise I imagine... because we talking about instances where currencies like euro are transferred to something that is much more volatile and much more (undefined) and I don't mind the argument of protecting investors there but I definitely see why the government will try to make regulations. It is a very difficult and lengthy process and they have to be some regulations for well transferring cryptocurrencies back to established cryptocurrencies and there has to be some umm... some focus on who is actually controlling the software of cryptocurrencies but I don't think the government should be so far as to completely control the whole system because as soon as this is happening people will not use cryptocurrencies anymore because... well...

Evan: It's invalidated..

Florian: Yeah, it completely breaks with the intention of everything decentralized.. And of course there are different reason as to why people want to use cryptocurrencies... you can say they want to do some criminal activity.. Okay other people only want to have their privacy, that is completely valid but in both cases the state people are just dropping out. So umm.. Yeah very difficult question.

Evan: Okay so I generated 2 more questions from your answer... First of all what about regulations specifically on stable coins? Which they are a bit of a weird category on the crypto world?

Florian: I am not quite sure about these ones to say I didn't look much into stable coins umm.. Yeah yeah, what are your thoughts about this first maybe and then see if I have something upon that.

Evan: Sorry I didn't hear your last sentence

Florian: So maybe if you can provide 1 or 2 inputs you have on that already and see if I have something to add.

Evan: The main issue, at least the one stable coin I am looking at Tether is it uses some different mechanisms not proof of work not proof of work... the idea is that they can produce and reduce the amount of dollars... usdt's their kind of dollar at any second depending on the market so they can have a specific price... Tether is 1 dollar at a specific time. The issue is there is a claim in their whitepaper and website and everywhere you at official paper.. They say every single of the dollars they have is backed by a dollar in their reserves. Well, this company in less than 4 months during the bull market from the start of the year until a couple of months ago umm.. They increased their position from 20bil to 64bil and it keeps rising and refuse to be audited.

Florian: Ok, I see...

Evan: (undefined) This category is no produced from mining and their inherent value in only depends on what exists in their reserves.

Florian: Ok I see, that is a very interesting case to compare with proof of stake or work cryptocurrency system. Indeed that's (undefined) that cryptocurrencies have this mechanisms they are directly connected to established currency and then when you have stable coins.. Yeah the one you are talking about now at least they have to claim and then when you have this claim you can say as regulator you have something to work here because we see the direct.. The direct relation to cryptocurrency value which isnt influenshed (undefined). I think that is very interesting to compare on the other hand I would say if they don't show transparency that is very very critical as well.

Evan: The issue is no one has to tell them, force them to be transparent because there are no regulations. Noone can come and say "show me".

Florian: Exactly, yeah. I think the regulation question especially at the moment if you look at bitcoin is hugely interesting if you look at El Salvador. Then the question of regulations becomes increasingly complicated if the whole countries commits to this digital currency as one of the forerunners there umm... But yeah I have toi say if you talk to regulations in cryptocurrencies we are not at the stage to make any results from studies, experiments. It is all just happening in a gray zone of trying things out... seeing if the work with regulations but on a very limited scale.

Evan: It too early to go...

Florian: Yeah I think so. Not too early to think about it but too early to make some regulatory frameworks that would (undefined) all potential systems they have. That's what I would say.

Evan: So in hypothetical future when cryptocurrencies are more massively adopted by the population and possible very much regulated by the government do you believe

people will care about decentralization privacy and stuff like this or use them because reasons.

Florian: Well, I think there needs to be something that catches people because we have perfectly functioning financial systems at the moments. We can trade money digitally anyway, that's nothing new. The new thing is the privacy aspect and share information and security but at the moment the cryptocurrencies if you take the bitcoin network for example now.. If people talk about cryptocurrencies people think of bitcoin network if you are uniformed that is. As long as this (undefined) and the biggest crypto networks are not stable enough to really guarantee security and guarantee privacy unless they are already really informed like you and me. So that is the challenge formed from the cryptocurrency side and as long they have solved this they will be credited from any traditional means. They may say we may think about integrating cryptocurrencies in our banking systems but before that happens I think its very difficult process to convince the majority of the public.

Evan: So now that bitcoin is being use as a legal tender in El Salvador and some other South American countries consider this... How are they gonna deal with the lack of rules?

Florian: Yeah this is exactly the interesting question why this is happening right now and how it shapes out?

Evan: Yeah.

Florian: I cannot give you direct answer to that I am also curiously following it but this is definitely a big step from a governmental actor to say would try it out and that is definitely a big step for establishing these systems more. This can either way create a huge boost for cryptocurrencies and understanding of it when other countries say "Okay they tried it out les see what we can learn from that". On the other hand if this fails then I am afraid it would take another 10 year before we can talk about this again.

Evan: I understand. Another interviewee mentioned that the way blockchain works right now in the environment is pretty similar to when the internet started. Would you believe there is some thrufh to that or they are different type of technologies and they follow different rules.

Florian: I definitely see when the similarities are from, why they used this as an example. Well, the beginning of the internet was just used by universities to communicate and send data but now you can go for shopping in the internet and well, you can exchange much more data than previously though, you can store things there and you know. Yeah, (undefined) and I definitely see this kind of development with cryptocurrencies. 100%. If I look at my own research I first looked at the financial sector and now I am looking in the energy sector. The technology itself didn't say that much but applications are a whole different case.

Evan: Would you like to give me some examples?

Florian: Yeah of course, if you want to use the blockchain to store financial transaction that is of course perfectly possible but also you can store knowledge. A professor I think he is in Harvard , when he gives a course on cryptocurrency and blockchain technology

he gives the certificate of its cred rates and stores it on the blockchain. So he establishes a form of knowledge storing which is safe as long as blockchain exists. There is a huge potential thee for archived to store blockchain to store digital copies of their files. I think that is very interesting and show how much more potential there is just from the technical side and if we also include the social side and we say, we have more actors in a decentralized system then there a lot of (undefined) possible that are very interesting only now coming out.

Evan: This is very interesting because now it makes me think that its true that the blockchain as an idea can be done with pieces of paper and follow the same formula of decentralization..

Florian: Yes, exactly.

Evan: ..and this is very very interesting.

Florian: If I can make another comment if you look at the whitepaper of Nakamoto as the first, birthplace of blockchain technology and more like the really first case of making some application possible , you can read from a financial perspective and say yeah this is perfect for our banking system but if you don't know about, right? It is used as a ground for creating cryptocurrencies but in theory and the infrastructure does not need to be connected with the financial sector, it is not specifically mentioned in the paper itself that it is just for financial aspects. I think this a good starting point that there is more to it than the financial side not as an economist but from a social side or librarian you can see some structures that are interesting to you.

Evan: This is also very true I think with the Ethereum network and especially the smart contracts and how they operate.

Florian: Yes, exactly.

Evan: This Is an implementation of something different than just a currency.

Florian: Yeah exactly, that the functions and this what I described in the thesis and what you can find in the academic literature, he functions of the normally centralized actors for example a bank. The bank controls the transactions, the bank (undefined), the hands out the money. If you give your money to the bank they have all your money and now all these functions are on the network and we share and validate our transactions on our own as individuals in the network. Money is distributing also in a decentralized way though the mining process. All these functions are decentralized and this is what it makes this so special. For smart contracts you don't need the bank to say the conditions are fulfilled this contract is happening right now but the network itself completes these contracts. You don't need a person controlling these.

Evan: How do you thing if in a possible future for some reason governmental official decide to go against specific cryptocurrencies and try to targe them through legal mean. Do you think this is a potential danger or maybe it is too big to fail right now ? What is the situation according to your opinion?

Florian: I think, it can go either way I have to say. I must say people will always use cryptocurrencies cause they are (undefined) so the question can they maintain the

current geeks that use cryptocurrencies and that's it okay we have this already, I mean you can trade with cryptocurrencies and have no idea how they function right? That is basically the level we are right now. You can buy NFTs even if you have never heard of cryptocurrencies before.

Evan: That is very true.

Florian: But yeah if we have some regulations or governments try to battle specific cryptocurrencies umm I think that would definitely have influence on the public and if regulators see the potential in blockchain technology they also see the potential in the financial sector. This is not a direct answer (undefined)

Evan: No no, its pretty understandable. Let's go back to the technology because the 2 most prevalent ways to

Florian: Produce cryptocurrencies are proof of work and proof of stake, generally speaking of course. At least in the environmental side and energy department proof of stake is impossibly better than proof of work I am talking about thousands and thousands of times. Well.. Does proof of work has any advantages over proof of stake?

Evan: Yeah o thing the biggest advantage proof of work has is security right. You need to have this process where you put a lot of computational power and a lot of consensus from different nodes in the system to really ensure about that transactions are not double book are facilitated and no one can manipulate the network. So, the security aspect is the biggest think. For proof of stake in a case might appear that a person own the majority of the network and that the security is compromised.

Evan: The 51% attack...

Florian: Yes, of course. And with proof of work that is also possible but not at the current rate of nodes it becomes increasingly impossible to control the majority of the nodes. On the other hand, it also makes it insecure. I can show you an article here (shows article) it is an a newspaper and I am not sure if you can read it but it says something like: "How China and Elon Musk control Bitcoin", Because all of the mines, the most influential mines are in China with couple of being big corporations controlling so in theory of course it can throw over the whole network if they wanted.

Evan: Yeah and not only through mining but also through influence, what happened with Doge coin or Tesla first accepting Bitcoin and then being environmental damaging, influence is damaging.

Florian: Yeah and if I can add there, we are thinking about the environmental the environmental aspects proof of work will remain dominant as long as it is economically profitable. People will increase their hardware and increase their mining grids and mining as long as they can take a profit over the long term. That's why that is hard to see energy usage to go down. People still make profit and as long as you have that people will always try to jump in and participate.

Evan: Since you told me about the strength of proof of work which is the security and the economic department because people, well maybe not so a strength but the reason of its existence. What about issues with security proof of work has?

Florian: As I said, the issue is that people can compromise the network if they own the majority of the nodes in the network, even not the majority of the nodes that the majority of the computational power right? So if they have couple quantum computer they can easily solve the hashes so for a short time they can definitely control the network and do double booking, control transactions and as soon as this happens the whole network collapses because as soon as people realize the mistake and people can manipulate (undefined) you can wait a day and then all drops down because the whole idea behind it is gone. That is the biggest issue with security.

Evan: I have one more question about bitcoin and has to do with the journey it has been through, when first started people where trade it as joke later started to gain value, people took it more seriously, now it costs a lot, people are discouraged due to the high transaction costs and its started it look its gonna turn more like umm how is it called like gold like some storage some value storage.

Florian: Yeah.

Evan: Is this something that can happen or is gonna take another turn.

Florian: Yeah I think this is what a meant providing storage and I think this is very interesting to follow. First it was not very valuable, I mean everybody know this example with the guy that bought a couple of pizzas with bitcoin

Evan: Yeah hahaha..

Florian: (undefined) I think the biggest development step was first of all the fork that happened with bitcoin network with bitcoin cash which was one of the biggest forks there. Very interesting if you want to talk about who owns the network and who owns the software and what kind of power is the software there and that is a big step I would and the second big step that is coming is that established first and actors like banks and stakes like El Salvador say “Ok you can for your Tesla now with bitcoin you can pay for your transactions in the store with bitcoin” and that is the first instance that the traditional money and the bitcoin network are overlapping and once this gets established then I think there will be a huge development in application cases again.

Evan: Is it healthy for the cryptocurrency ecosystem?

Florian: Oh that is very philosophical question I have to say

Evan: You studied haha..

Florian: Yeah, I would personally say it is healthy if you see, sifting power from very few individuals, very few corporations towards more stakeholder, if you see that as healthy then I would say yeah definitely because even if it doesn’t develop there at least there is a conversation about it. There is research about it. People think why are we actually...

Evan: Yeah if I get this correct maybe a few people gather the wealth from bitcoin

Florian: No I meant it more in a general way. So, I also think the term healthy a bit not that fitting, I would say “is it challenging power relations in society” definitely. Is this a good or develop into something good? I don’t know, nobody knows for sure now at

least but it definitely challenges the established systems and infrastructures we have and I personally think that is good these are challenged from time to time. I mean we are talking about throwing over the banking system from one day to another but that there is conversation going that is created out of these new technologies. I think that is a good development.

Evan: So it is something natural in a way?

Florian: Umm I would say (undefined) process or something but sooner or later somebody challenging established governments and established frameworks, whether that is a criminal or interesting or just someone who wants to do something different or make profit that isn't relevant I think. What is relevant is how the established systems react tot hat. That is interesting to see.

Evan: Okay I see we are running out of time. Last question. A general comment about the future of blockchain and the future of cryptocurrencies. What do you see?

Florian: Umm I say big things are coming next years, definitely I mean now I really focus on the energy sector and I can tell you from my impressions the next 3 or 4 years will see an insanely increasing bloom of activity. From not all the very specialized people but also from the broader public and I think that is hugely exiting. In the financial sector I think there is a lot of interesting things coming out of establishing cryptocurrencies in traditional, well economic context and banking systems but with these interesting movements big challenges arise as well.. Not saying they will hinder or advance development but it is definitely a lot of room for negotiations and reflection and I really look forward to that.

Evan: I just want to mention that I believe the questions (today) where a bit more theoretical from at you expected.

Florian: No...

Evan: Oh no, I just wanted to say the reason is because I do 4 cryptocurrencies and that is large amount when we go into details it becomes difficult. I decided to take step back and see what I can see generally.

Florian: No, I think as you said in the beginning that you try to compare these cryptocurrencies but definitely see that you come into some problems trying to fit all of them into one thesis. I think it is good to take a step back. Umm yeah if I may give another comment or something or something because I have to say I was mostly interesting on you tackle the environmental aspect is very interesting.

Evan: Shall I tell you?

Florian: Yes please.

Evan: The idea first of all when I started planning my thesis, my scope was to focus purely on the environmental effect as I started studying about this I realized the different possibilities blockchain has with proof of work, proof of stake, different technologies here and there. Which led to the idea of making a comparison of these different stuff only on the environmental effect specifically and the sustainability. What I realized as I was going on is that when I was focusing specifically on the environmental effects I

was losing a lot of other stuff that are interconnected the political aspect, the legal aspect, the technology, the markets the economics, everything. So I realized that this is a whole system interconnected. Bitcoin for example is very polluting but has some other advantages and have to be mentioned so I couldn't make a comparison and disregard all this stuff and this was the approach. Does this answer your question?

Florian: Yeah, no I think this is very interesting and vey good approach, I like that, yeah I just want to hint you at, well this is the paper that got me into my research focus and is very connected to the environmental focus (undefined). I have send you the link in chat. Is the environmental history of computing. Do you know the paper?

Evan: This one specifically no so thank you very much!

Florian: No no, it starts how the consumption of computing technologies but then it also has a paragraph about cryptocurrencies especially the bitcoin network so that might be very interesting for you and one think I did not manage to fully explore in my thesis and is till miss my academic literature and this can be good for your thesis. If you look at the environmental aspects of cryptocurrencies what is missed there people look at the energy direct consumption but don't look in the secondary energy consumption, they just measure how much energy is sued in the mining system or in the mining facility but what about the cooling elements of the mining facilities, what about the that is used for the hardware creation before the mining even starts. All these energies costs are not accounted at all and also not in the academic literature and that is really what bugs because there are huge amounts of energy used that are not mentioned at all.

Evan: Well, so actually I am using life thinking so I do touch a bit upon like for example I want to use CPU for mining what is like, how much does it cost and stuff like this but I stepped into some problems with this. Due to the huge amount different materials different companies producing different usages umm its very difficult and I am still thinking if I include some rough estimations or simply mention it.

Florian: Maybe to (undefined) I wouldn't try to measure the exact amount because this is very difficult and a lot of people tried that and failed so don't do this but I wanted to say at least it needs to be acknowledged like hardware costs hardware production..

Evan: Which is very difficult to map out.. Yeah I agree with this very very much and uhh it is an issue I stepped upon and that is why I said I use life cycle thinking and life cycle assessment because if used the assessment part it would have been numbers and that yeah...

Florian: Yeah.. I see. And yeah, the second thing I send you is a book mastering bitcoin, I used it a lot for my thesis. It really really explains, at least only the bitcoin network this is one the basic literature if ant to dive into the bitcoin network. I can really recommend it.

Evan: Thank you very much for all the help and very interesting conversation and like really thank you for the whole interview. I think we can stop the recording .

Florian: Yeah exactly haha.

End of recording