Cryptocurrency mining using renewable energy

An eco-innovative business model

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Abstract:

The purpose of the study was to explore and describe the phenomenon of cryptocurrency mining using renewable energy through the investigation of innovative business models. The focus was on crypto-mining companies located in Europe, which use renewable energy to power their operations. The aim of the research was to find answers to the research questions about sustainable cryptocurrency mining as a concept, about the future of the industry, as well as to identify if their business models can be considered eco-innovative. The study was limited to cover only the cryptocurrency mining centers that rely on renewable energy for their business and are situated in Europe. The theoretical studies included concepts of business model, eco-innovation and eco-innovation in business models. The empirical study consisted of three interviews with the representatives of three cryptocurrency mining centers that rely on renewable energy, as well as two e-mail interviews with expert cryptocurrency researchers. Additionally, information on cryptocurrency mining as a business and energy consumption by crypto-mining was gathered. The description of renewable energy was also covered. The results showed that cryptocurrency mining using renewable energy is a growing business niche driven by maximizing profits through using the cheapest renewable energy available. Such a business model could be defined as eco-innovative. The study also speculated on the potential future of crypto-mining and could not come to a definite conclusion. Ideas for future studies include cryptocurrency evolution and its applications and impact on other industries, and development and implementations of Blockchain technologies in various sectors.

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CONTENTS

Figures

Tables

1 INTRODUCTION

1.1 Background and the need for research

Cryptocurrency mining has received a significant amount of public attention recently due to its rising energy consumption. This was mostly due to numerous headlines in the press presenting cryptocurrencies as a serious climate threat with their insatiable appetite for electric power. (Imran 2019 p.2) The process of mining cryptocurrency does require a lot of processing power that relies on an uninterrupted energy supply. (Giungato et al. 2017 p.2) Together with a growth in the number of various cryptocurrencies released into circulation throughout the world, the energy consumption has increased substantially, leading some to believe that these tendencies might result in cryptocurrencies using a significant amount of global energy. (Li et al. 2019 p.1-2) Though this might seem absurd, there is some truth to this, as the amounts of energy consumed by mining operations are still alarmingly increasing. (Hern 2019) How much of global energy is actually being consumed to produce cryptocurrency is debatable.

However, in recent years, many companies have emerged that have chosen to turn to renewable energy sources, in locations where these sources are abundant, to support their mining operations. Their business models differ from other mining centers that still rely on fossil fuels-derived energy. These companies can show that even highly energy dependent processes can benefit from using renewable energy.

There has been little to no research done about sustainable cryptocurrency mining. Thus, there seems to be a gap in research in this field. On top of that, the author feels that it is a fascinating subject where many new findings can be made, and where there is a potential for further and more in-depth research.

1.2 Core definitions

The following definitions are very industry specific and are taken from the sources that specialize in the cryptocurrencies and related topics. Knowing these core concepts, in the author's opinion, is crucial in order to understand the study.

Altcoin - alternatives to Bitcoin (BTC) (e.g. Ether, Ripple, Zcash, Monero, etc) Currently there are hundreds of different cryptocurrencies in circulation with new ones appearing all the time. (Bitcoin Magazine)

Bitcoin (BTC) is the first decentralized cryptocurrency created in 2009 by pseudonymous developer Satoshi Nakamoto. It is a platform that hosts a digital ledger on which people can mine, store and trade bitcoins. It is a digital form of currency earned through a computer algorithm and tied to no central authority. (Bitcoin Magazine)

Blockchain provides a decentralized digital database of transactions, also known as a distributed ledger, which is maintained and updated by a network of computers (nodes) that verify a transaction before it is approved and added to the ledger. (Morkunas, Paschen and Boon 2019)

Cryptography deals with information encryption using mathematical operations that allow to achieve confidentiality and integrity of data or perform authentication or authorization procedures. (Ogiela & Ogiela 2017)

Double spending – a risk that a digital currency can be spent twice. Double-spending is a potential problem unique to digital currencies because digital information can be reproduced relatively easily. (Investopedia)

Distributed ledger is a database that is consensually shared and synchronized across multiple sites, institutions or geographies. It allows transactions to have public "witnesses," thereby making a cyberattack more difficult. The participant at each node (computer) of the network can access the recordings shared across that network and can own an identical copy of it. (Investopedia)

ICO (Initial Coin Offering) is a fundraising mechanism in which new projects sell their underlying crypto tokens in exchange for bitcoin and ether (coins with monetary value). It is similar to an Initial Public Offering (IPO) in which investors purchase shares of a company. (Bitcoin Magazine)

Proof of Work (POW) is the original consensus algorithm in a Blockchain network. Proof of Work is a system (or protocol, or function) that requires computers to exert extra computational effort in order to complete a process or task. This extra computational effort results in a solution, which can then be presented and verified before the desired process or task is executed. (Komodo 2018)

Proof of Stake (POS) concept states that a person can mine or validate block transactions according to how many coins he or she holds. This means that the more Bitcoin or altcoin owned by a miner, the more mining power he or she has. (Investopedia)

Security token represents a share in the company and is a digital asset that has value of an external asset and can be traded. Security token are also called equity tokens. (TheTokenist) Security tokens are also subject to national legislation that governs securities. They are heavily regulated by the government and failure to comply with the regulations may result in severe consequences. (Hackernoon)

Token (crypto token) represents a particular exchangeable and tradable asset or a utility that is often found on a blockchain. (Investopedia) Tokens are not a currency. They are symbols of a contract, where value does not depend on mining. Unlike cryptocurrency, to issue a token one does not need to create a blockchain, but use an existing one (e.g. Ethereum, which was originally created as a platform for smart contracts and evolved to be a currency). (Coin Telegraph)

Utility token is defined in Merriam-Webster dictionary as a digital token of cryptocurrency that is issued in order to fund development of the cryptocurrency and that can be later used to purchase a good or service offered by the issuer of the cryptocurrency. (Merriam-Webster dictionary). These tokens are not investments. (Hackernoon)

1.3 Purpose of the study and research questions

The purpose of the study is to explore and describe a phenomenon of cryptocurrency mining using renewable energy through investigating their innovative business models. The focus will be on the crypto-mining companies located in Europe, which use renewable sources of energy to power their operations

The aim of the research is to find answers to the following questions:

1. What is a sustainable cryptocurrency mining business?
2. Can crypto-mining based on renewable energy be defined as an eco-innovative business model?
3. What is the potential future for this industry?

1.4 Limitations

The study relies on the academic research covering cryptocurrency and its impact on the environment, which is very limited at the time of the study being conducted.

The concept of sustainable cryptocurrency mining is relatively new and there has been little research made on the subject which limits the amount of theoretical knowledge to be accumulated for the thesis.

At the time of the thesis being written cryptocurrency mining could go through further changes (e.g. new protocols introduced for mining, governmental legislation, global sustainability regulations, etc.) which would affect the validity of the thesis.

At the time of research there is a narrow pool of companies to base the research on. The number of existing companies who practice sustainable mining and who are willing to contribute to the research are limited. The companies researched are limited in their geographic locations, i.e. the companies used in this research are situated in Europe and only represent the European cryptocurrency mining facilities. Globally, there are other companies that rely on renewable energy, but they will not be the focus of this research.

The author uses the term cryptocurrency when referring to Bitcoin and all the altcoins (alternative coins) in order to simplify the scope of the research.

Another limitation related to the technicality of the term cryptocurrency mining is that not all cryptocurrency can be mined depending on the algorithm that is being used, thus, for this research, when referring to "cryptocurrency mining", we assume only those cryptocurrencies that can be mined in the first place.

1.5 Structure of the thesis

The thesis is divided into 7 chapters. The first chapter covers the background of the topic, need for research, the purpose of the research and statement of the problem with the core research questions.

The second chapter defines cryptocurrency and clarifies the problem behind its unsustainable mining operations. In this chapter the author explains how cryptocurrency mining is done and why it is so energy dependent. The researcher will also give an overview of what renewable energy is.

The third chapter covers theoretical background of business models, also describing the concept of eco-innovation. We will also find out what business models can be identified as eco-innovative.

The research method, the reason for its selection for this thesis and challenges in data collection and research execution are explained in chapter four.

Chapter five briefly presents the three companies that are studied for this research, providing an insight into how these new cryptocurrency mining businesses function and where they procure their energy supplies for their mining operations. The chapter also presents the two expert researchers in the field of Bitcoin and cryptocurrencies who have been involved with cryptocurrencies for the past 5-6 years.

In chapter six we will analyze the data collected via the interviews. The main findings of the empirical research, the analysis of the data and recommendations for further research on the topic are also presented in this chapter.

The conclusions of the thesis and final words on the subject are stated in chapter seven.

2 CRYPTOCURRENCY MINING

2.1 Cryptocurrency

Cryptocurrency can be defined as a digital medium of exchange based on cryptography and secured by math. It is a virtual currency that allows secure, decentralized economic transactions. (Vejacka 2014 p.75-82) Cryptocurrency is based upon a technology called "the blockchain protocol." The blockchain is the basis for a public decentralized ledger that records all transactions and removes the financial middleman. (Maese et al. 2016 p.470) The main attributes of cryptocurrency are that it has no physical form, nor fundamental value. It only exists in the decentralized network of nodes (computers). There is no central entity that governs it, so its entire economy is public, transparent and is monitored by peer-to-peer protocol. Its supply is not overseen nor controlled by any government or central banks.

Here are some main aspects of cryptocurrency:

1. It provides freedom of payments to its users (user can send/receive any amount quickly and anywhere in the world)
2. It offers payments with no fees
3. Cryptocurrencies are transparent (i.e. all information about money supply is available in blockchain in real time)
4. No organization or individual can manipulate the protocol because cryptocurrencies are cryptographically secured
5. Payments are pseudonymous and provide a high degree of anonymity
6. Transactions are irreversible and secure
7. Total value of cryptocurrencies is smaller than fiat currencies

8. Many cryptocurrencies are still in development. There is potential for growth
9. Total supply is predetermined and increases via mining
10. Cryptocurrency exchange rates are highly volatile
11. Easily portable due to virtual character, but also non-existent outside electronic environment (Vejacka 2014 p.75-82)

2.1.1 What is cryptocurrency mining?

As we mentioned earlier cryptocurrency has no fundamental value. To create value, one needs to have something that is scarce (e.g. diamonds have high value because of their scarcity in nature). In the digital world, scarcity can be designed by solving computational problems which require time to resolve. That is what happens in cryptocurrency mining. (Narayanan 2016 p.14)

Mining is the process by which a cryptocurrency is produced. It is the process of adding transaction records to the blockchain's public ledger of past transactions by pushing transactions into blocks. Mining is a very competitive, power-consuming process that requires expensive hardware. Miners are solving artificial mathematical problems, algorithms, which form the basis of cryptographic proofs, by dedicating their computational power to the network (proof-of-work protocol). (Vejacka 2014 p.75-82)

At the moment, it is hard to list all the existing proofs, because new ones are being developed all the time. Some examples of the types of proof are Proof of Work, Proof of Stake, Proof of Space, Proof of Time, and even some theoretical proofs, like Proof of DDoS. (Lielacher 2017) For the purpose of this research we will not explain all the technical aspects of all the different proofs and only briefly describe the most widely used proof, proof-of-work. "Proof-of-Work mining secures cryptocurrency as a decentralized and distributed network, it ensures coins are distributed fairly within a competitive system." (Imran 2018 p.11.)

The key idea behind proof-of-work is that we are allowing nodes (computers) to compete with each other by using their computing power to continuously solve puzzles. Whenever one of the nodes gets lucky it gets to propose the next block in the blockchain. That is

why the system is completely decentralized. There is nobody deciding which node gets to propose the next block. (Narayanan 2016 p.115-126). The nodes keep solving mathematical problems, validating transactions and releasing currency into circulation. Using a lot of computing power in proof of work is highly energy dependent, and because most cryptocurrencies are using proof-of-work algorithms, it makes mining cryptocurrencies highly energy dependent as well. The proof-of-work protocol is compute-intensive and very energy demanding, but crucial for avoiding double-spending and securing the blockchain. (Vranken 2017 pp.1-9.)

Some people compare mining to a lottery due to its competitive nature. In that case winning it would mean your new block becoming a part of the blockchain, so that the other nodes of the network would validate the block and retransmit it. (Investopedia) Mining comes with its rewards: transaction fees for the transaction validation, as well as the newly released coin itself.

It is also worth briefly noting three of the main types of mining that exist nowadays. First there is rig mining that includes solo or pool mining. This type means a miner can use his/her own hardware to mine solo or cooperate with a group of miners to form a “pool” (i.e. to compete more effectively by combining their mining power). Pool mining allows even smaller miners have a chance of earning at least a part of the reward (Bitcoin), that is distributed between the pool miners depending on how much power they contributed. (Bitfalls 2017) Then there is cloud mining which is renting remote hardware to mine and is paid for in regular currency. One would use shared processing power in a remote data center to mine without the hassle of managing your own equipment and all the inconveniences associated with it (e.g. cooling, noise, resale of equipment or extra electricity costs). (CoinDesk) Lastly, there is browser (web) mining. It takes place when a mining program is implemented in a browser (website or webpage) and cryptocurrency mining is performed through the browser by using the CPU/GPU of a website visitor while a webpage is open. (SecurityTrails 2018)

2.1.2 Hardware

We have seen that mining requires solving mathematical problems and is computationally difficult. Here we will take a quick look at the hardware needed for these computations. (Narayanan 2016 p. 115-126). This insight will help understand how energy reliant mining is.

The first generation of mining was all done on general purpose central processing units (CPUs), which simply ran the code. Now, CPU mining is no longer profitable with the current levels of difficulty. That is why a second generation of mining emerged when people started using graphics processing unit (GPU) instead. Mining with a GPU required simple setup with graphic cards that were easily available. It was also possible to combine several GPU's to increase the mining efficiency and profitability. However, GPU's used a lot of electricity, and building a multi-GPU setup required buying expensive hardware. (Narayanan 2016 p.115-126)

In 2011, some people started to use Field Programmable Gate Arrays (FPGAs) which offered better performance and easier cooling than GPU's. Nonetheless, FPGA mining was not long-lasting. Today mining is dominated by ASICs, or application-specific integrated circuits. These are chips that were designed, built, and optimized for the sole purpose of mining. (Narayanan 2016 p.115-126)

Crypto-mining has evolved from CPUs to GPUs to FPGAs, to now ASICs. It also evolved from being more accessible for individuals into mining done by large companies with larger capitals and, consequently, larger profits. Another interesting fact about crypto mining is that most of the profits have been earned by those selling/renting equipment (ASICs), at the expense of individuals hoping to get rich. (Narayanan 2016 p. 144) With the evolution of mining hardware from CPU's all the way to ASIC's came exponential increase in performance and energy efficiency. (Vranken 2017 pp.1-9.)

2.2 Energy consumption and ecology

The first law of thermodynamics states that energy cannot be created nor destroyed. It is always converted from one type to another. In our case, the computation requires energy

from electricity to do the work whereby the energy is converted into heat and is transmitted into the environment. (Narayanan 2016 p.115-126)

Energy consumption is inevitable for cryptocurrency mining. There are 3 steps in the process of mining where energy is required:

1) *Embodied energy.* Energy for manufacturing mining equipment.
2) *Electricity.* When the ASIC is powered it consumes electricity. With more efficient mining rigs, the electricity costs will go down. However, the need for electricity will remain and the demand for it will increase as mining difficulty and scale increase.
3) *Cooling.* To keep the mining machines in working condition and prevent their malfunctioning, cooling is vitally important. If the mining is done in the cold environment, the cooling costs will essentially be lower. The energy needed for cooling is in the form of electricity as well. (Narayanan 2016 p.115-126)

When determining where to set up a mining center, the three biggest considerations are: climate, cost of electricity, and network position. In particular, you need a cool climate so that cooling costs will be low. Access to cheaper electricity could provide a financial benefit when the rewards outweigh the electricity costs. You also would need to be well connected to other nodes in the peer-to-peer network. (Narayanan 2016 p.115-126)

2.2.1 Mining on a larger scale

Theoretically speaking anyone with access to the Internet, the appropriate hardware and supply of electricity could mine even at home, which many people do. At some point it was the standard way to mine and make profit. However, nowadays crypto-mining is an industry on a large scale, with professional mining centers developing where electricity cost is kept low. Exact details about how these centers operate are not very well known because companies want to protect their setups to maintain a competitive advantage.

These types of mining centers are the focus of this research. In the following chapters we will find out about such mining centers and, specifically, those that use renewable energy to maintain their mining operations.

When mining on a larger scale both embodied energy (energy for equipment manufacturing) and electricity decrease (per unit of mining work completed). It allows one to mine more efficiently. Additionally, it is cheaper to build chips designed to run in a large data center and deliver power more efficiently since you don't need as many power supplies. The real expense comes from cooling, as it actually costs more for larger scale facilities. Running a large-scale operation, where the equipment is installed in one place with little air circulation would need very good cooling to make sure the computers do not overheat. Cooling larger facilities is more difficult and, thus, pricier as well. (Narayanan 2016 p.115-126)

2.2.2 Estimated energy consumption

At the moment, there is no precise method to calculate energy consumption by cryptocurrency mining because cryptocurrencies are decentralized networks and because miners operate all around the world without documenting what exactly they are doing. (Li et al. 2018 pp. 160-168) We face several challenges when estimating electricity consumption:

1) Number of cryptocurrencies is hard to define and can change every day.
2) Any computer with proper software can be doing mining activity, making it hard to estimate the number of miners.
3) Cryptocurrencies are untraceable, making it hard to recognize the status of mining activity. (Li 2018 pp. 160-168)

Nonetheless, the estimation of overall electricity used for mining is enormous. (Li et al. 2018 pp. 160-168) Li et al in their thorough study on energy consumption on cryptocurrency mining conclude “that energy consumption will keep increasing. More energy efficient and environmentally friendly algorithms are needed in developing cryptocurrencies.” (Li et al. 2018 p. 1) The researchers also warn that “the secondary energy consumption should be further studied. Energy consumed when mining is exhausted as heat

into the indoor environment, which increases the cooling load of cooling systems." (Li et al. 2018 pp.160-168)

Several studies have been conducted in an attempt to estimate the energy consumption of cryptocurrencies, e.g. "Energy consumption of cryptocurrency mining: A study of electricity consumption in mining cryptocurrencies" by Li et al (Li et al. 2018); "The Positive Externalities of Bitcoin Mining" by Saad Imran (Imran 2018), or "Sustainability of bitcoin and blockchains" by Vranken.H (Vranken 2017). Despite all the interest in the subject, at the moment the problem seems to be too complex to give a concrete answer on how much energy is consumed globally for cryptocurrency mining purposes. Most figures of electricity consumption are based on assumptions. A couple of examples could be Digiconomist with estimated annual electricity consumption by Bitcoin of 63 TWH (TeraWatt hours) in 2018 (Digiconomist), while Bevand predicted electricity consumption by mining in 2018 to be between 14 and 27 TWh. (Bevand 2017) As we can see the estimations vary significantly. The only thing evident is that the amounts of energy used for crypto-mining worldwide are substantial and growing. (Li 2018 pp. 160-168). The graph in Figure 1 shows the Bitcoin Energy Consumption Index with min 3,30 TWh from early 2017 rising up to 37,00 TWh in the end of April 2019. (Digiconomist)

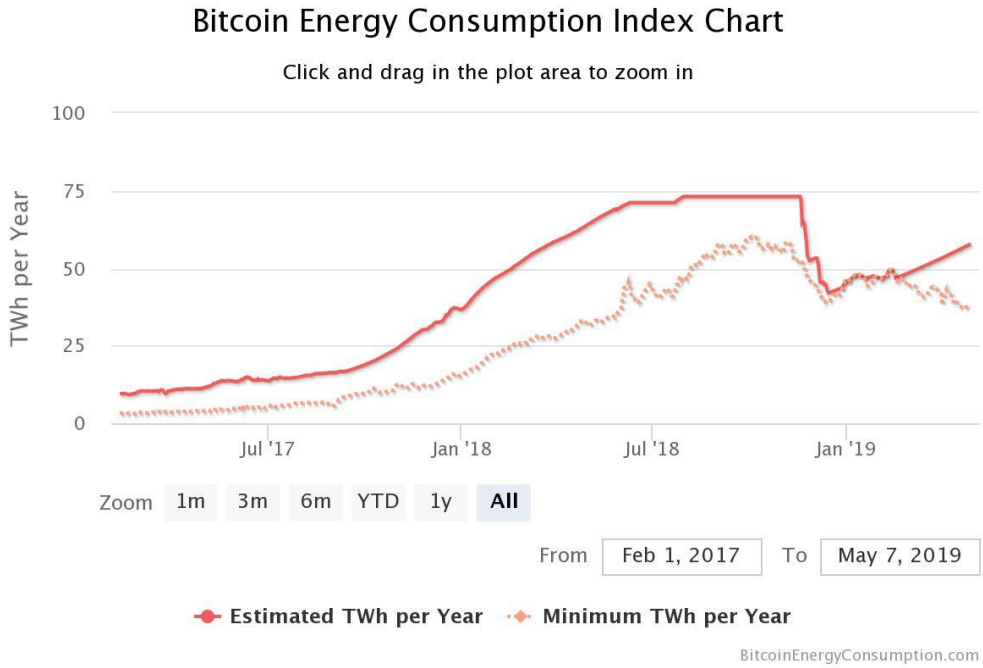

Figure 1. Bitcoin Energy Consumption Index. (Digiconomist 2019)

A short note on TeraWatt hour: terawatt-hour is a unit of energy which equals to outputting one trillion watts for one hour. This value is large enough to express annual electricity generation for entire countries and is used when describing major energy consumption/production. (EnergyEducation)

2.3 Renewable energy

Now we have a better picture of what cryptocurrency is and how it is produced. We found out that mining operations require a lot of electricity, which comes mainly from fossil fuel resources (just like the vast majority of any electricity worldwide). Next, we will take a look at what renewable energy is and whether it can be used for crypto-mining.

Renewable energy can be defined as energy that is infinite within a timeframe relevant to humanity. This energy comes from three main sources: the Sun, planets and the Earth. It can, thus, be categorized as Solar, Planetary (gravitation) and Geothermal. Coming from the primary source, the energy is being converted by natural processes into other energies, e.g. Solar energy converts into wind, waves, currents, precipitation, etc. Energy from the Sun is not just the sunlight and the heat that we normally associate with the solar energy. It is wind and hydro energy as well, among others. For us to collect this converted energy we need the help of technology. That is why we construct solar towers, wind turbines, river power plants, etc. By collecting this natural energy with special technology, we can then produce secondary energy in the form of electricity, heat or fuel. (Quaschning 2016 pp.21-31)

Theoretically, the renewable energy supply is far greater than the entire global demand. This is good news; however, the problem is that compared to fossil fuel the renewable energy supply can fluctuate (e.g. wind). (Quaschning 2016 pp.21-31)

Nuclear power, even though considered a sustainable source of energy, is not a long-term alternative to fossil fuels due to the very restricted reserves of uranium needed for nuclear fission. As we have mentioned earlier a renewable source of energy is infinite, therefore,

nuclear power, although greener than some alternatives, is a non-renewable source. (Quaschning 2016 pp.16-19)

BNEF Global Trends in Renewable Energy Investment of 2018 says that investments in renewables have continued to increase each year. The leading force behind the investments was developing countries. Since 2004 the world has invested $2.9 trillion in green energy sources. The renewable energy market continues to progress at a remarkable rate. In 2017, global investment in renewables exceeded $200 billion. Switching to renewable energy sources shows commitment to addressing climate change and reducing carbon emissions. (Frankfurt School-UNEP Centre/BNEF 2018)

The share of renewable power in global power generation reached nearly 8.4% in 2017, almost doubling in five years from 4.6% in 2012. (BP Statistical Review of World Energy, 2018) Consequently, we see some positive trends towards renewables in global power generation.

In 2016 while total world energy came from 80% fossil fuels, 10% biofuels, 5% nuclear and 5% renewable, only 18% of that total world energy was in the form of electricity. (Shell world energy model a view to 2100, 2017). The majority of energy we consume is derived from fossil fuels, but many aspire for these percentages to drop in the near future in favor of renewables.

2.3.1 Cryptocurrency mining using renewable energy

Being able to provide enough energy at the lowest cost is the main criterion for a physical location of a cryptocurrency mining center. S.Imran believes that miners will not choose the origin of energy supply based on whether it has negative impact on the environment, but rather on profit alone. He claims that it is difficult to “determine the percentage of mining performed using fossil fuels relative to renewable energy today due to the lack of data.” Nonetheless, he predicts that “in the long-run miners will increasingly seek renewable sources as opposed to fossil fuel energy sources.” (Imran 2018 p.11)

In his article, Imran speculates that hydro and nuclear power sources are ideal for mining due to their stable nature, unlike wind which can fluctuate. The study also suggests that in the long-run it could be strategically beneficial for miners to choose areas where electricity is produced using renewable energy due to declining marginal cost relative to fossil fuel generated electricity. (Imran 2018 p.11)

Interestingly, Imran also claims that the cryptocurrency mining industry "provides one of the first mechanisms in which there is a reward to participants for efficiently utilizing energy." The idea is that with more competition, more investments will be made into renewable energy sources to lower marginal costs of mining, which will result in "innovative Proof-of-Work mining system improving the efficiency and allocation of our energy usage worldwide." (Imran 2018 p.11)

3 ECO-INNOVATION IN BUSINESS MODELS

We have now looked at what cryptocurrency is, how it is produced and what the cryptocurrency mining industry has evolved into. The concept of renewable energy has also been explained.

In this chapter the author will explore the concept of "business model" and business model innovation. The chapter will also investigate the phenomenon of eco-innovation and the possibility of eco-innovation in business models. These concepts will add to our understanding about what sustainable cryptocurrency mining is and whether we can consider it an eco-innovative business model.

3.1 Business model

Business model is a rather old concept, that surfaced in the academic literature together with the concept of business strategy of Porter & van der Linde (1995). (Joller 2012 p.3) In recent years, however, the idea of business model has been researched with higher levels of attention by scholars. There are now a number of different ways of understanding and defining a business model. Despite all the attention and research conducted on this subject, the existing definitions of business model are barely overlapping, giving space

for various interpretations of what a business model really is. (Joller 2012. p.2) Even though, according to Zott et al. (2011), academics still do not agree on an explicit definition of business model, for the purpose of this research we will try to accumulate knowledge from various sources and draw our own conclusions about business model as a concept. (Zott et al. 2011 p.216-226) In order for us to understand the eco-innovation in business models it is crucial to have a clear idea what business model is.

Johnson et al. (2008) break down business model into four elements which together create value. These core elements are

- Customer value proposition (CVP), which includes target customer, job to be done to solve an important problem for the target customer, and offering, which satisfies the problem. The main characteristic of a CVP is its precision, meaning how perfectly it manages to get the customer job to be done.
- Profit formula is essentially a plan of how the company creates value for itself while providing value to the customer.
- Key resources are people, facilities, technology, etc. which help create value for the customer and the company.
- Key processes are managerial and operational processes that can consistently support value creation. They can be manufacturing, sales, R&D, training, etc. (Johnson 2008 p.3-5)

In short, Teece (2010), concludes that business model is "about the benefit the enterprise will deliver to customers, how it will organize to do so, and how it will capture a portion of the value that it delivers." He believes that ideally a business model "will provide considerable value to the customer and collect (for the developer or implementor of the business model) a viable portion of this in revenues." (Teece 2010 p. 176)

Morris et al have come up with a definition of a business model as a "concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets" (Morris et al. 200, p. 727)

The Casadesus-Masanell and Ricart's (2010) approach is slightly different, where they describe a business model as a reflection of a firm's realized strategy and note that concepts of strategy and business model differ. They also insist that every business has a business model, but not every organization has a strategy. (Casadesus-Masanell. R., Ricart, J. 2010 pp. 195-215) The difference between business model and strategy will be explained later on.

Osterwalder et al. (2005) defines a business model as "a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm. Therefore, we must consider which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences." (Osterwalder et al. 2005 p. 3) The researchers also identify the building blocks among business models in the existing literature on this topic. The nine blocks cover all business model components mentioned in the literature excluding competition and implementation related components. (Osterwalder, et al. 2005 p. 10) Figure 2.

Pillar	Business Model Building Block	Description
Product	Value Proposition	Gives an overall view of a company's bundle of products and services.
Customer Interface	Target Customer	Describes the segments of customers a company wants to offer value to.
	Distribution Channel	Describes the various means of the company to get in touch with its customers.
	Relationship	Explains the kind of links a company establishes between itself and its different customer segments.
Infrastructure Management	Value Configuration	Describes the arrangement of activities and resources.
	Core Competency	Outlines the competencies necessary to execute the company's business model.
	Partner Network	Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value.
Financial Aspects	Cost Structure	Sums up the monetary consequences of the means employed in the business model.
	Revenue Model	Describes the way a company makes money through a variety of revenue flows.

Figure 2. Nine Business Model Building Blocks (Osterwalder, et al. 2005 p. 10)

As we can see from all these definitions, the main attributes of a business model are fairly similar, including core value, target customer, some set of operations and processes, dif-

ferent communication and distribution channels which altogether create value for the firm and the customer, and help the company gain profit and an advantage over its competition.

3.1.1 Business model vs. Strategy

It is important to mention that there is no unanimous agreement among scholars on whether business model and strategy are the same thing or two different concepts. However, a practical distinction describes business models as a system that shows how the pieces of a business fit together, while strategy also includes competition (Magretta 2002 pp. 86-92)

Business model literature focuses on identifying the elements and relationships that describe how a company creates and markets value. (Osterwalder et al. 2005 p. 7) In their Clarifying Business Models article, Osterwalder et al point out that there is a major difference between strategy and business models, where strategy includes execution and implementation, while the business model is about how a business works as a system. Osterwalder claims that both strategy and business model cover similar issues but on different business layers. He also identifies business model as “the strategy’s implementation into a conceptual blueprint of the company’s money earning logic”. (Osterwalder 2005 pp. 3-10)

The researchers report that many authors talk about successful business models. Osterwalder et al believe, however, that a business model can be coherent but would still need to be implemented. Just as a “good” business model can be implemented poorly and fail, a “bad” business model can succeed thanks to skillful implementation. (Osterwalder et al. 2005 p. 7) According to other researchers, business model implementation means the "translation" of the business model as a plan into business structure, business processes and infrastructure. (Brews, P.J., Tucci, C. 2003 pp. 8-22)

3.2 Eco-Innovation

The 'Innovation Impacts of Environmental Policy Instruments' project has introduced the term environmental innovation (aka eco-innovation) in 1999: "Eco-innovations are all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which; develop new ideas, behavior, products and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets". (Klemmer et al. 1999 pp. 9-30)

Eco-innovations can be achieved by firms or non-profit organizations, they can be traded on markets or not, their nature can be technological, organizational, social or institutional. (Rennings 2000 pp. 319-322)

According to Joller.L (2012), eco-innovation can be interpreted as a "concept which provides direction and vision for pursuing the overall societal changes needed to achieve sustainable development." (Joller 2012 p. 2)

In the European Union the concept of eco-innovation is promoted through the Environmental Technology Action Plan (ETAP). Their definition of eco-innovation is "the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)". (ETAP) Eco-innovation supports the objectives of the EU Lisbon Strategy for competitiveness and economic growth. (Joller 2012 p. 2)

The Organization for Economic Cooperation and Development (OECD)'s definition combined with the definition from the methodological report of Eco-Innovation Observatory (2012) resulted in the following definition: "Eco-innovation is the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle". The newer and shorter version of 2012 is "Eco-innovation is any in-

novation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle." (Methodological report 2012).

Interestingly, eco-innovation can be both intentional and unintended, where e.g. an innovation is a side effect of other goals such as reducing costs for production or waste management. The concept of eco-innovation puts emphasis on reduction of environmental impact whether such an effect is intended or not. (Machiba 2010 p. 359).

3.2.1 Eco-innovation in business models

In this section we will try to understand the idea behind eco-innovative business models and what their main characteristics are.

The idea of business model innovation when a company could create an original business model that never existed before, or modify a current business model, has entertained the minds of business leaders for a long time. Innovative business models do exist in every sector of the economy. They keep challenging established ways of creating and capturing value. (Zilahy 2016 p. 62)

After several surveys conducted with managers and entrepreneurs, Amit and Zott conclude in their article "Creating value through business model innovation" that there are several reasons why business model innovation seems more attractive compared to traditional product/process innovation: 1) new model represents underutilized sources of future value; 2) innovation at the business model level can be a feasible performance advantage over competition, because it is much harder to replicate the entirely new activity than a single product/process innovation; 3) business model innovation can be a potentially powerful competitive tool (Amit, R., Zott, C. 2012 pp. 41-49) Johnson et al. (2008) believe that business model innovation is more important for success of the company than product or service innovation. (Johnson et al. 2008 pp. 3-5)

Lindgardt et al state that business model innovation "can be most powerful when it is approached proactively to explore new avenues of growth," especially in critical periods

when companies search for new moves to reconfigure an existing business. (Lindgardt et al. 2009 p. 2)

Business model innovation is more than just an innovation of a service or a product. It occurs when two or more elements of a business model are reinvented and can deliver value in a new and original way. Business model innovation is hard to execute because it includes multidimensional set of activities. (Lindgardt et al. 2009 p. 2) It can also help address external changes (e.g. regulations), that dictate the need for new competitive approaches. (Lindgardt et al. 2009 p. 2) According to Lindgardt et al. (2009), business model innovation also requires two or more of the business model elements to be changed. (Lindgardt et al. 2009 p. 2)

For a company to maintain its competitive position in the market or even just to enter the market, it usually needs to eco-innovate to keep up with the competition, to abide with new regulations or to satisfy eco-conscious customers. Traditionally, more sustainable solutions meant product or service innovation. Today, however, the scope for innovation has grown into organizational level i.e. implementing new business models and original value propositions. Joller (2012) theorizes also that "from the macro-economic perspective, it has also become obvious that technological eco-innovations alone are not capable to create incremental change at an expected pace to reach the EU 2020 climate change and energy targets, therefore a more radical eco-innovation approach is needed to achieve the systemic change. The solution may lay in the eco-innovation in business models." (Joller 2012 p. 2)

Joller (2012) suggests the following definitions of eco-innovation in business models, based on the studies of Osterwalder's (2005) and the OECD Methodological Report: "Eco-innovation in business model is (change in) the logic/way/rationale how an organization offers its customers value (and creates sustainable revenue streams), while reducing the use of natural resources and decreasing the release of harmful substances across the whole life-cycle." (Joller 2012 p. 7)

In her study on eco-innovation in business models, Joller (2012) presents her interpretation of Ekins' (2010) three possible routes that a product/process, that delivers a more

sustainable environmental performance, can take. (Ekins 2010 p. 267-290) (Joller 2012 p. 3) Figure 3.

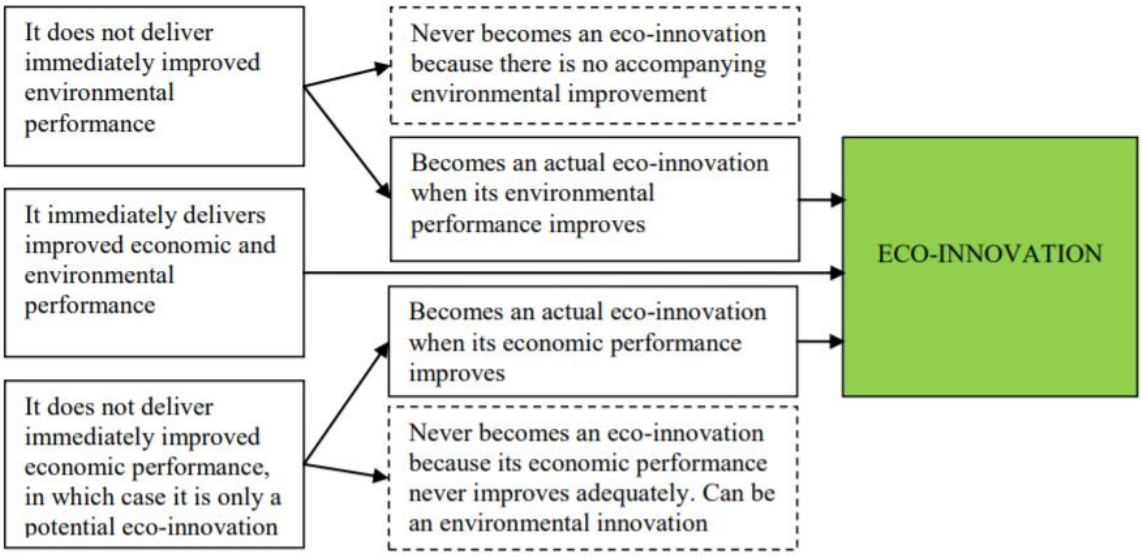

Figure 3. Possible eco-innovation trajectories. (Joller 2012 p. 3)

Implementing eco-innovativeness into the business model is not easy, because not only does it have to help the company achieve long-term competitive advantage and be economically feasible, but it also needs to maintain a sustainable usage of resources.

Boons and Lüdeke-Freund (2013) have reviewed relevant literature on business models and formulated basic requirements that a business model has to fulfill to be an eco-innovative model: 1) "the value proposition should provide measurable ecological and/or social value," 2) "suppliers should take responsibility for their own and their suppliers' stakeholders," 3) "customers should be motivated to take responsibility for their consumption and for the stakeholders of the companies involved in the supply chain," 4) "economic costs and benefits should be distributed appropriately among actors and should account for the company's ecological and social impacts." (Boons 2013 pp. 9-19) The described requirements are devised by Boons and Lüdeke-Freund (2013) and do not represent the universally accepted requirements for a business model to be eco-innovative.

After reviewing 87 examples of different companies, an advisory firm, SustainAbility, in their report on 20 Business Model Innovations for Sustainability, identified 20 business models that can produce more sustainable outcomes for the environment and society. These models are divided into 5 groups:

1) **Business models with a potential positive impact on the environment.**

   - *Closed-Loop Production:* The material used to create a product is continually recycled through the production system.
   - *Physical to Virtual:* Replacing brick and mortar infrastructure with virtual services.
   - *Produce on Demand:* Producing a product only when consumer demand has been quantified and confirmed.
   - *Rematerialization:* Developing innovative ways to source materials from recovered waste, creating entirely new products.

2) **Business models aiming at social innovation.**

   - *Buy One, Give One:* Selling a specific good/service and using a portion of the profits to donate a similar good/service to those in need.
   - *Cooperative Ownership:* Companies owned and managed by members, often taking broader stakeholder concerns into account, including those of employees, customers, suppliers, the local community and in some cases, the environment.
   - *Inclusive Sourcing:* Retooling the supply chain to make a company more inclusive, focusing on supporting the farmer or producer providing the product, not just the volume of the product sourced.

3) **Base of the pyramid business models**

   - *Building a Marketplace*: Companies build new markets for their products in innovative and socially responsible ways, including delivering social pro-

grams, adapting to local markets, and bundling with other services like micro-finance and technical assistance.

- *Differential Pricing*: Realizing customers may benefit from the same product but have different payment thresholds, companies charge more to those who can afford it in order to subsidize those who cannot.
- *Microfinance:* Providing small loans—and in some cases access to financial services—to low-income borrowers who do not have access to a traditional bank account.
- *Micro-Franchise*: Leveraging the basic concepts of traditional franchising, but specifically focusing on creating opportunities for the poor to own and manage their own businesses.

4) Innovative financing models.

- *Crowdfunding*: Enabling an entrepreneur to tap the resources of his/her network to raise money in increments from a group of people.
- *Freemium*: Offering a proprietary product or service free of charge, but charging a premium for advanced features, functionality or virtual goods.
- *Innovative Product Financing*: Consumers lease or rent an item that they can't afford or don't want to buy outright.
- *Pay for Success*: Employing performance-based contracting, typically between providers of some form of social service and the government.
- *Subscription Model*: Customers pay a recurring fee, usually monthly or annually, to gain ongoing access to a product or service; model has been used to lower barriers to entry to the purchase of green innovations.

5) Business models with diverse impacts on sustainability.

- *Alternative Marketplace:* When a firm avoids a traditional method of transaction or invents a new type of transaction to unleash untapped value.
- *Behavior Change:* Using a business model to stimulate behavior change to reduce consumption, change purchasing patterns or modify daily habits.

- *Product as a Service:* Consumers pay for the service a product provides without the responsibility of repairing, replacing or disposing of it.
- *Shared Resource*: Enabling customers to access a product, rather than own it, and use it only as needed; often dependent on the participation and generosity of community members to share their goods with others. (Sustain-Ability 2014 pp. 8-9)

In his research, Machiba (2012) unveils the economic, social, cultural and environmental benefits of various sustainability-oriented business models presented in Table 1.

The sustainability benefits of various business models (Machiba, 2012)

Business model types	***Core value propositions***	**First-order value creation**		
		Economic	***Social/cultural***	***Environmental***
Green value-added products	*Products with better performance, savings*	Savings and better performance for customers Profit for focal company and its suppliers	Green image	
Waste regeneration systems	*Revenue from waste valorisation, alternative products*	Revenue from waste valorisation, alternative products	Green image/ bio brand	Minimisation of the impact of waste
Renewable energy-based systems	*Cheaper & cleaner energy*	Cheaper energy for customers Profit for focal company	Green image	Minimisation of the reliance on fossil fuels
Efficiency optimisation by ICT	*Economic savings due to more efficient management of resources*	Profit for focal company		
Functional sales	*More efficient services*	Savings for customers	Convenience	
Innovative financing	*Resource savings*	Profit for focal company	Convenience	
Sustainable mobility systems	*Flexibility, savings for customers*	Savings for customers Profit for focal company	Flexibility	
Industrial symbiosis	*Resource savings, higher efficiencies*	Resource savings	Learning	Waste and emission reductions
Eco-cities	*Improved quality of life, convenience*	Improved quality of life Green image	Improved environment	

Table 1. The sustainability benefits of various business models. (Machiba 2012)

Using Machiba's table of sustainability benefits of business models we can conclude that our research is centered on renewable energy-based business models which use cheaper and cleaner energy and, thereby, maintain a green image of a company that does not rely on fossil fuels.

4 METHODOLOGY

In this chapter the author will describe and justify the selection of the research method used for this study.

The thesis attempts to answer the following research questions:

1. What is a sustainable cryptocurrency mining business?
2. Can crypto-mining based on renewable energy be defined as an eco-innovative business model?
3. What is the potential future for this industry?

The author identified the purpose of the research as the exploration of sustainable cryptocurrency mining through the analysis of the business models of leading companies in the segment.

According to J.K. Sachdeva. 2008, "exploratory research relies on secondary research such as reviewing available literature […], or qualitative approaches. The results of exploratory research can provide significant insight into a given situation." (Sachdeva 2009 pp. 165-170) Due to the exploratory nature of the research, a qualitative study method was the best suited approach for this thesis. By implementing this method, we could collect more detailed information on the subject. Qualitative methods give us flexibility in the study of complex phenomena in dynamic environments with a variety of interpretive techniques e.g. case study, in-depth interview, observation, etc. (Carson 2005 pp. 61-73)

4.1 Method

From the array of various qualitative research methods an in-depth interview would be the most promising and productive in collecting first-hand information from industry specialists. Out of the three types of interviews (unstructured, structured and semi-structured) most qualitative research relies on the unstructured or semi-structured interview. Unlike structured interviews that offer direct questions, more comparable responses and lack of variability of questions, unstructured interviews help develop a dialogue with an interviewee and let the researcher extract a greater variety of data and more elaborate answers to the questions. (Sachdeva 2009 pp. 165-170) For the purpose of this study the author has chosen to proceed with semi-structured interviews in order to obtain more comprehensive answers from the participants.

The companies interviewed for this research are among the few existing and most known sustainable cryptocurrency mining companies in Europe at the time of the study being conducted. These companies have been selected purposively because their characteristics fit with the criteria of the research (located in Europe and mining cryptocurrency using renewable energy sources).

The primary data presented in this study was collected through a series of five interviews: two semi-structured face-to-face interviews with the CEO's of Hydrominer and Moonlite Project, and one e-mail interview with the Head of Mining Operations of Genesis Mining (Philip Salter). The author also conducted two e-mail interviews with two leading researchers in the field. One researcher is a representative of Digiconomist, a platform dedicated to exposing the unintended consequences of digital trends from an economic perspective (Digiconomist). The other interviewee is the Head of Research in CoinShares, a digital asset management platform.

Semi-structured interviews gave the author access to the first-hand information, from the people in the business, which would otherwise be unavailable from literature. By interviewing the people who pioneered sustainable cryptocurrency mining we gained a lot of invaluable information and insight on the future of this business from experts in the field. An in-depth interview "is a useful method for exploring new and under-researched topics.

Its overall strength is its ability to gather rich and meaningful data, analysis of which will lead to a significant depth of understanding that would be difficult to achieve by using any other method alone." (Carson 2005 pp. 73-92)

4.2 Challenges in data collection

It is always challenging to get access to the right people for interviews, to get them to agree to participate in the research, to coordinate the interviews with their busy schedules, to choose the right mode of interview (face-to-face or e-mail) that would be convenient for the participants and to prepare for any unexpected scenarios during the interviews.

Interviewing requires the researcher to possess a set of certain skills like making a respondent comfortable, probing for detail, encouraging the participant to talk openly, listening carefully, following a participant's train of thought, being able to extract information from a participant who is unaware that s/he possesses the information desired. (Sachdeva 2009 pp. 165-170) The author of the thesis is not a professional interviewer and might lack special characteristics to conduct a high-quality interview, which could have also resulted in some limitations in the data collection.

Another challenge related to the chosen research method is the fact that interviews rely on the ability of the interviewer to conduct the study and analyze the data with minimal bias, and it is very difficult to eliminate human factor while conducting qualitative research and interpreting the results.

The chosen method for the research is a semi-structured interview. The challenges with this method are that the questions asked, and their interpretations fully depend on the interviewer (i.e. the researcher). The information gathered through the interview depends on what questions were asked and how the topics were developed during the interview. As with any qualitative research (e.g. observation, focus group interview or content analysis), the information is filtered through the researcher's bias and relies heavily on the researcher's analytical skills. There are possible limitations and possible lack of richer

data collected through the interviews due to some level of inadequacy of the questions or failure to notice an important piece of information in the interviewees' responses.

5 PRESENTATION OF THE COMPANIES

At the moment, the majority of mining is done in China (approximately 70%), where the main source of energy for mining comes from fossil fuels. Some companies, however, recognize the risk of this unsustainable business and look for alternative and future-proof mining. (Hydrominer)

In the following chapter we are going to present the three companies, that are using renewable energy sources in their cryptocurrency mining centers. We will introduce their concepts and general business idea behind their operations. The chapter will also introduce two expert researchers of cryptocurrencies who, based on their knowledge and experience, can offer a more objective insight into crypto-mining.

5.1 Hydrominer

Hydrominer is an Austrian company that pioneered sustainable cryptocurrency mining. The company currently mines cryptocurrency on a larger scale using only sustainable energy sources.

The company was founded by Nadine and Nicole Damblon in 2017. The sisters were already experienced in mining and, after realizing how highly energy-dependent mining was, decided to start their own mining operations where renewable energy would be the primary source of energy. They called their venture Hydrominer. The mining center is located in Lower Austria in the Alps where they rent two privately owned hydro power stations with direct access to hydro power to support their operations. In 2017, the first mining operation with over 800 GPU's started in Schönberg am Kamp, where Hydrominer rents an entire power station. Another station opened in December 2017 near Waidhofen an der Ybbs, where they built a mining farm with the funds raised from the ICO (Initial Coin Offering). There, they deployed ASIC and GPU mining units, renting the base energy of 470 kW. Hydrominer is situated in one of the most ideal locations for

cryptocurrency mining. Austria with over 3000 hydro power stations, low energy costs for hydro power (3-5 cents/kWh) and suitable temperature for mining offers a perfect spot for the company that relies heavily on electricity. (Hydrominer; Interview with Nadine Damblon)

Having specialized mining equipment is crucial for a mining business. Hydrominer works with both GPU's (with which one can mine various altcoins like Ether and Zcash) and ASICs (with which one can mine all Bitcoin algorithm currencies like Bitcoin and Bitcoin Cash). The Hydrominer team also has a strong relationship with various hardware dealers to ensure they have their equipment up to date. (Hydrominer)

Hydrominer monitors their mining centers 24/7 with a web dashboard to make sure that temperature, hashrate, wattage, fans and memory are all operating within optimal range.

Through the first ICO Hydrominer managed to raise 3 million dollars in capital. The company issues H2O tokens, which are vouchers for mining time in the Hydrominer facilities. One H2O equals to a minimum of 5 kWh of energy but, depending on the hardware and market situation, the team can decide if they allocate more kWh. Since February 2018 H2O Tokens can be exchanged into mining time in their mining portal. HydroMiner offers GPU and ASIC Mining not only for H2O Token holders but also against EUR /USD and cryptocurrencies. Customers can also choose if they want to mine Bitcoin, Bitcoin Cash, Ether, Ether Classic or Zcash. (Hydrominer)

At the time of the research the company was having problems with the EU financial market authority which did not allow the company to operate and to issue security tokens directly to its customers unless they had a license to do so. Because of their small size the company would not be able to get the necessary license and had to close their operations in Austria. Nadine Damblon explained that the company was in a transition stage where they were looking for locations outside the EU to continue their affairs without compromising their core idea of sustainable crypto-mining. (Interview with Nadine Damblon)

5.2 Moonlite Project

The concept for Moonlite Project was born in February 2017. Since then the business plan has been developed, and the company's ICO launched in January 2018. The ICO raised more funds than expected with ca $22 million invested in the project compared to the estimate of $12 million. The mining operations are to take place in data centres in Iceland with ca 21 MegaWatts electricity capacity generated from 100% renewable sources (wind, geothermal, hydro). The location was selected especially because Iceland has a naturally cool climate. That would eliminate the need for expensive cooling infrastructure, while maintaining high operational efficiency. (Moonlite)

Iceland's electricity supply is nearly CO2 free as a result of hydro and geothermal power. Geothermal energy (geothermics) utilizes the heat of Earth's interior. Geothermal power stations can use geothermal heat and convert it into electricity or send it to district heating systems. Due to radioactive decay deep inside the planet, the Earth's interior temperatures can be between 3 000°C and 10 000°C. Today geothermal energy is only utilized in places with geothermal anomalies. These regions record high temperatures at low depths. Such regions with record high temperatures at low depths are very few in the world. Geysers are good indicators of such locations. Iceland and the Philippines are the main options for geothermics, where it provides more than 20% of the electricity supply. (Quaschning 2016 pp. 20-21) Being able to utilize locally available cheap geothermal energy in a cold climate was the decisive factor for the Moonlite Project to choose Iceland for their mining base.

The Moonlite project is a subsidiary of Capetivo Group. They intend on mining Bitcoin, Bitcoin Cash, Dash and Litecoin. (Moonlite)

The company's scale is the largest in Europe so far with a lot of funding from investment funds and an estimated 22 MegaWatts of operational electricity consumption by the 3rd quarter of 2019. The company is planning on expanding their footprint by constructing more large-scale mining facilities which would rely exclusively on renewable energy. The company can also boast having a team of professionals working on the project along

with the AI technologies that together would guarantee maximized profits and efficiency. (Moonlite; Interview with Eric Krige)

5.3 Genesis Mining

Genesis Mining was founded in the end of 2013. The company claims to be the world's largest hashpower provider that has made a name for themselves in the crypto community since 2014. Marco Streng along with a group of other Bitcoin enthusiasts founded the company to create a global player in the crypto mining market. The company's operations are optimized and stable, that is why they believe they can be profitable even in the hard times. The current team members come from various scientific disciplines but share a common belief in the future of the digital currencies.

Genesis Mining claims to be spending a lot of effort and time to automate as many aspects in the company as possible. They manage to run a large mining farm with a small number of workers on site. This allows them to run mining farms even in those places where labor costs are very high (Iceland, Sweden). (Interview with Genesis Mining; Genesis Mining) By setting up their data centers in such locations as Sweden and Iceland, Genesis Mining also aims at achieving maximum output with minimal costs. They are utilizing cheap renewable power sources while at the same time cutting down on the need for temperature management systems (i.e. cooling). (NewsBTC)

The mining farms of the company are situated in Iceland, Canada, and Bosnia. The exact locations of the mining centers are not disclosed for security reasons. (BitCoinWiki)

5.4 Cryptocurrency Researchers

In order to obtain the information for the research from various professional points of view, the author conducted e-mail interviews with two leading experts in the cryptocurrency community. Their work has been cited in reputable publications such as Bloomberg and The Economist.

Christopher Bendiksen from CoinShares expressed his viewpoints based on years of experience in research in the world of cryptocurrencies. Christopher is the Head of Re-

search at CoinShares, Europe's largest digital asset manager. He has been involved with cryptocurrencies since early 2013 and has held his current position at CoinShares since August 2017.

The second participant is a leading expert on Blockchain and cryptocurrencies. He contributed to the research by providing his insight on the subject based on years of experience in the field of cryptocurrencies. He has been a Blockchain specialist at PwC since 2015, and writing/doing research regarding Bitcoin since 2014 via his website digiconomist.net.

Being able to obtain and analyze the information from both mining companies, who might be over-optimistic about their business, as well as from independent cryptocurrency experts gives us a wider and a more realistic representation of the sustainable crypto-mining phenomenon.

6 FINDINGS

This chapter aims at providing answers to the research questions based on the information collected both through literature and empirical research. The answers to the research questions will help us realize the purpose of the study which was exploring sustainable cryptocurrency mining as examples of eco-innovative business models. First, we will introduce the findings from the interviews.

6.1 Findings from the interviews with the companies

1. All three companies initially wanted to have access to affordable electricity for their mining operations. Hydrominer had an opportunity to negotiate a deal with owners of small privately-owned hydropower stations to use their facilities. Nadine told us that: "Here's [in Austria] a lot of small hydro power stations, […] over two thousand small ones […] We just went to the countryside and we looked at a few hydro power stations. We had an idea to bring the hardware to these hydro power stations because it's a perfect set up in our opinion to use the energy there […] We fit into that small niche and use that energy." Setting up their infra-

structure in those power stations provided them with cheap green energy which they valued, and which was the core principle of their business model.

Moonlite Project also searched for cheaper electricity and chose to establish their mining farm in Iceland because of the cheap green energy supply as well as its cooler climate. Even though Iceland was not their first choice, after researching countries where electricity could be affordable and come from renewable sources, Iceland stood out as the best location for the project. The Moonlite Project CEO, Eric Krige, gave us an explanation of how their operations ended up being established in Iceland: "Really early on we were looking at the Middle East, like Qatar. (because of cheap electricity) And very quickly, when we did research, we found out that they were using oil and oil-based products to generate 100% of the electricity. And even though the prices were fairly cheap we then switched to a country which we started researching simultaneously, that was Iceland. […] Iceland, being in the Nordics is a much cooler climate. […] In the hot country or basically any country that isn't actually cold you have a massive heating issue and quite a lot of money gets spent on installation of a conditioning system. […] So, probably from the middle of twenty seventeen we knew it would be Iceland."

Philip Salter, the Head of Mining Operations at Genesis Mining, told us that the company was initially interested in using hydro power, which is "the cheapest energy on the planet", and that the company was not pursuing purely ethical argument when selecting the renewable power source for their operations. He stated that "renewable energy is important for protecting the environment. It's also cheap!"

2. Both Hydrominer and Moonlite emphasize the importance of relying on renewable energy for mining as the core value and part of their business mission. Even in circumstances where fossil fuel-derived electricity and electricity from renewable sources are available at similar prices the choice falls on renewables. The choice for locations of mining centers is mostly dependent on the electricity price and the climate. When setting up a mining farm it comes down to a combination of ethical reasoning and the attractiveness of the project to potential investors. In the case of

the Moonlite Project both these factors led the company into choosing renewable energy sources in the cool climate of Iceland. According to the company CEO many investments would not have happened if not for the fact that the company is using 100% green energy. His words were that: “Sustainability is written into our mission statement as a core focus of the company. We would never enter an environment where we couldn’t use green energy.” He also stated that: “There are literally countless instances [when] several dozen people specifically said, “We have invested in this project because you're using green energy.”

The Hydrominer CEO, Nadine Damblon told in the interview that: “the first factor was our idea to use green energy because it is important to us. But it wouldn’t have been possible without the low energy price that we had here in Austria.”

Philip Salter had a more pragmatic approach, emphasizing that “people like making money and they like being a part of the crypto revolution.” However, he added that people also want “to make sure they are supporting something sustainable.” So, using renewables is more of a side effect of going after the cheapest power that can help bring higher returns from mining.

3. Using renewable sources of energy might mean that some extra expenses should be expected. However, setting up a mining infrastructure and buying mining equipment still requires an initial investment whether the company goes green or not. Nadine told us that: “we [Hydrominer] were lucky to have this cheap green energy here [in Austria], but of course when you go inside a hydropower station and put your hardware there you need to do some adaptations and that can cost up to 200 000 euro per hydropower station.”

   Genesis representative told us that the company’s “production/operation costs are lower than most others’. We spend a lot of effort and time to automate as many aspects in our company as possible.”

   The costs of electricity and cooling are lower for the company if the mining center uses locally supplied cheap green energy in a region with a low average tempera-

ture. It seems that setting up a mining center in a cooler climate where renewable energy is accessible, at similar or lower prices than fossil fuel-derived energy, is more cost effective. Eric shared his vision of where crypto-mining is likely to be concentrated in the future: “Places like Canada and the Northern States of US, like Montana, North Dakota, Washington, all those cold Northern US states which are on the Canadian border, that's where you’re going to find mining centers to concentrate.” So, perhaps, Scandinavian countries, Canada and Northern states in the US could potentially be the future locations for crypto-mining centers (also due to their stable political situations).

4. The success of a cryptocurrency mining firm also depends on their business model. In the case of Hydrominer, issuing security tokens to the end customers resulted in the company having to shut down its operations. Security tokens are treated as securities depending on local laws and are, thus, subject to heavy regulation. A small-scale company like Hydrominer was unable to obtain a license to continue their operations and was forced to look for other locations outside the EU. “It's not possible for a company of our size to get this license. It's just impossible,” explained Nadine, adding later that the company also received a decision from the tax ministry saying “we [Hydrominer] don't get the VAT back for the hardware we buy”. Complications with tax authority and the EU securities regulations made it impossible for the company to continue operations in Europe.

   The Moonlite Project, on the other hand, are issuing utility tokens which do not fall under the EU security laws. The company’s token holders have a say in the important matters of the organization where they can express their opinions on corporate matters. The Moonlite Project holding company is registered in the British Virgin Islands where the ICO was conducted. Their Iceland operations are not seen as publicly funded nor as a token-based business. Moonlite’s Icelandic mining farm is a locally registered privately-owned business and is not subject to the EU securities directives.

Eric (Moonlite Project) shared in the interview: "I would like to think that once we are operational […] we would be setting a good example and our standards will be the benchmark for the industry. I believe some of the items that we just briefly glossed over now in terms of our own technology and AI […] to the best of our knowledge other companies aren't doing that. […] I think it would be great if other companies were to use our standards as the benchmark and improve their business model." He also explained that mining companies are not really competing but are rather "working for the same purpose that's the stability of the blockchain."

Genesis Mining is currently one of the largest cloud mining companies in the world who sells Bitcoin mining contracts. The company emphasizes the importance of optimized operations and automation. They develop and use Genesis Hive as a full management solution for their mining farms. Philip Salter has similar views about the industry as Eric Krige, saying that "it's important that companies don't just improve internally but also work with the community as a whole. We want to ensure that mining stays decentralized and fair for everyone. Mining needs to get more sustainable, because it's also the cheaper option and cheaper always wins". Using cheap renewable energy for profitable mining while supporting the future of Blockchain seems to be the shared goal for these companies.

5. These companies represent very different approaches to the same business idea. One is a smaller scale pioneer of sustainable cryptocurrency mining that aims at offering benefits directly to the end customer and relied on their ICO to fund their business. The second is a grander scale company in its early stages with big investments from investment funds, larger capital and an entire data center at their disposal for mining, while the third company is the largest cloud mining company on the market with proven track record since 2014. All are cryptocurrency mining centers, and all take pride in using renewable energy for their operations, but each has a different business model in the same industry.

6.2 Findings from the interviews with the researchers

1. Both researchers from CoinShares and Digiconomist agree on the idea that the main reasoning for the companies to start using renewables is purely economic. Christopher Bendiksen of CoinShares clarifies his opinion saying "Bitcoin mining is extremely competitive which results in a relentless race to the lowest global electricity prices. That space is dominated by stranded and/or underutilized renewable electricity sources, mainly hydro power." The researcher from Digiconomist, claims that "mining companies look for the cheapest source of electricity. If that happens to be sourced from renewables, then it's a bonus at best."

2. Whether renewables-based mining operations are more or less profitable compared to the fossil fuel dependent mining is a matter of debate. According to Christopher Bendiksen "mining profitability is highly dependent on your electricity cost. Due to extreme competition, only those miners with the lowest electricity cost will survive." He states that although many miners care about the environment, the majority simply aim at harvesting the cheapest energy possible regardless of its source. "The cheapest electricity in the world comes from stranded and/or underutilized renewables. This is the likely reason why they are used, probably not because miners care particularly much about the environment." The Digiconomist expert, on the other hand, believes that "it's [crypto-mining based on renewables] likely less profitable because renewables are an intermittent energy source. There's obvious fluctuations in demand as well, so that's hard to unite with mining that requires 24/7 non-stop power."

3. Both researchers agree on the idea that the investors are not influenced by the fact that the companies are environmentally responsible. Christopher shares with us that even though it is impossible to know for sure the reasoning of the investors, he does not believe "ethics plays a large part in the decisions of most miners.[…] In my experience though, they seem more profit- than ethics-driven."

4. The researchers believe that the companies which use renewables for their operations do not encourage any technological innovations. According to Digiconomist

expert, “they [the mining companies] can only make a difference with regard to cooling, which is already reaching a limit for most facilities.” Christopher explains that “Bitcoin miners will consume as much resources as the block reward can buy. There is no technological innovation that could make miners consume less energy. […] the whole point is to use as much energy as the market is willing to sell them.”

5. Speaking about the future of crypto-mining in general and sustainable crypto-mining in particular the researchers had two different opinions. While Digiconomist researcher believes “there is no future for cryptocurrency mining and […] that PoW [Proof-of-Work] will become obsolete at some point”, Christopher suspects that “mining is about to undergo a powerful professionalization development.” In his opinion there is going to be “vertical integration of power producers and miners” and that “mining will drive the development of new hyper-low-cost renewables that were previously uneconomical.” He thinks that there will be “deep financialization with the emergence of hashrate and/or difficulty derivatives, that post-hardware-commodification we’ll see grid operators and renewables producers with intermittent production integrate PoW hardware into their operations as flexible off-takers of variability caused by changes in production or load.”

6. According to Digiconomist, the future of environmentally responsible crypto-mining is unlikely. Besides the energy consumption factor, there is another issue with crypto-mining industry: “You can put as much “green” energy as you want in Bitcoin, but it’s still a significant e-waste generator (which ends up in environmentally damaging landfills and incinerators)”. Christopher Bendiksen argues that “if we [human race] can manage to lay off fossil fuels entirely then mining will of course also be fossil free. If we […] must keep fossil fuels, I think mining will keep being more renewables driven than most other industries, because it can buy the cheapest electricity (stranded renewables) wherever it is available, whereas most other industry and population demand is geographically captive and will pick fossil fuels because they can be produced near population centers”.

6.3 Answering research questions

1. What is a sustainable cryptocurrency mining business?

   Based on the results of the interviews and the literature review we can state that sustainable cryptocurrency mining at this point in time is cryptocurrency mining that is supported by the energy produced from renewable sources (e.g. solar, hydro, geothermal, wind). Nowadays, cryptocurrency mining is done on a larger scale with mining centers operating throughout the world. Sustainable crypto-mining tends to be in locations where renewable energy is abundant (possibly stranded) and more affordable than fossil fuel-derived electricity. It also aims at using more efficient hardware (e.g. ASIC's) to optimize energy consumption. The locations for sustainable cryptocurrency mining centers are at this point scattered throughout the world but companies tend to investigate cooler climate countries with secure and stable political and social situations (e.g. Iceland, Sweden, Canada).

2. Can crypto-mining based on renewable energy be defined as an eco-innovative business model?

   Eco-innovative business model is where the organization's way of creating value for customers and for the organization itself is directed at reducing the use of natural resources and release of harmful substances into the environment. Since crypto-mining centers that operate using only green renewable energy strive to offer value to their customers without compromising the environment they could be considered eco-innovative. The natural resources used for mining are renewable which means their supply is infinite in the timeframe relevant for humanity. Sustainable cryptocurrency mining today uses hydro power, solar energy, wind and geothermal energy. Using these power sources means the companies do not release as much CO2 into the atmosphere and minimize the negative impact on the environment.

Sustainable cryptocurrency mining companies implement more advanced mining hardware (ASIC's) and try to reduce power usage needed for cooling by building mining centers in colder locations. However, we can conclude, based on our findings from interviews and on Machiba's research (Machiba 2010) that in the case of crypto-mining using renewable energy, the eco-innovation is more of a side effect of the goals like reducing operational costs and cooling expenses. The concept of eco-innovation puts emphasis on reduction of environmental impact whether such an effect is intended or not. (Machiba 2010 p. 359). Cryptocurrency mining companies using renewables are unintentionally eco-innovative.

Cryptocurrency mining based on renewable energy can fit into several business models of sustainability devised by SustainAbility report. These could be business models with a potential positive impact on the environment (e.g. providing virtual services, producing on demand and using innovative sources for production), innovative financing models (e.g. customers renting equipment they cannot afford; crowdfunding or ICO), business models with diverse impact on sustainability (e.g. sharing resources). Altogether we can define crypto-mining based on renewable energy as eco-innovative.

3. What is the potential future for this industry?

The companies that took part in the interviews agree on the idea that cryptocurrencies will continue to exist and evolve. The mining is going to be done mainly by larger mining centers located in cooler climate countries where the local governments would allow these businesses to operate, meaning the taxes and legal regulations would not hinder the mining business. Based on their opinion we can conclude that there is a strong possibility that cryptocurrency mining will shift towards using renewable energy in the future. Some mining companies are turning to renewables in order to attract investors, get access to cheaper energy and maintain a sustainability conscious status in the community.

Nevertheless, the independent experts in Blockchain and cryptocurrencies believe that crypto-mining will either cease to exist or go through major changes (i.e. pro-

fessionalization development; financialization, etc.) One of the experts also assumes that crypto-mining is actually more likely to be renewables-driven in the future (in the areas where this energy is abundant) than any other industry, because mining is not geographically captive and data centers can be set up anywhere where the cheapest energy is plentiful. An opposing idea was presented by the second expert saying that even using renewables for mining is not going to make the industry much greener because of e-waste, and that overall mining on renewables "is a terrible match."

We heard optimistic views from the companies' representatives on the future of crypto-mining, however, we also need to consider the scenario where cryptocurrency mining can become obsolete just as quickly as it appeared. It is hard to predict how this industry will evolve, but it is important to consider all the possible outcomes. Nevertheless, we cannot deny that even if cryptocurrency mining is not going to exist in the future, the technology (Blockchain technology) behind it has a lot of potential applications and benefits in many industries.

6.4 Suggestions for further research

Cryptocurrency is a relatively new field of research in academia and there is still a lot of exploration to be done on this subject. The world of cryptocurrency is also evolving very rapidly, and many changes happen within short periods of time. In author's opinion, there is definitely a need for further research of cryptocurrencies, their development and the global changes they bring along with them in many other industries.

The phenomenon of cryptocurrencies can be studied from multiple angles: their application, their technological advancements, the good and the bad that comes along with their implementation (economical, technological, environmental, social, political, etc.) The subject is new with promising new avenues to be explored.

With development of the mining hardware, advancement of AI technologies, new algorithms combined with growth in investments into the green energy sector and into green

crypto-mining there is an interesting new field of research emerging that requires more attention from the academics and scholars.

The author feels that through researching cryptocurrency one can make interesting discoveries and get a better understanding of how Blockchain and financial technologies are changing the world we live in.

6.5 Discussion

Due to its exploratory nature, this thesis tackles the research problem based on the few studies that have already been done previously on the topic.

It is not quite clear whether cryptocurrencies will continue to exist. Their disruptive nature is both threatening and promising. The future of green cryptocurrency mining is unpredictable but there are a few possible routes the industry can take: development of various alternative consensus mechanisms to replace Proof-of-Work; new laws in different countries will either facilitate the entry into the business or ban it altogether; other technological advancements could make mining less energy dependent and more efficient; or the industry would die out as quickly as it appeared. In author's opinion it is hard to say at the moment what the future of sustainable cryptocurrency mining will be.

Cryptocurrency mining has evolved from individuals mining at home with their CPU's into large mining farms mining 24/7 with the most efficient hardware and AI to maximize the mining capacity. Cryptocurrency mining seems to also be on a path of switching from fossil fuel-based electricity to alternative and more sustainable sources of energy in pursuit for cheaper energy. Mining is a huge business and investors are interested in fast and high returns in new promising industries. With more investment pouring into the renewables sector it is possible that the cryptocurrency mining industry will take advantage of that and rely more on renewables as well in order to get more investment themselves.

Based on empirical data we can speculate that the number of cryptocurrency mining centers might grow with a few bigger players in the game. Larger scale companies that use

stranded renewable energy at reduced cost, have more investments and access to the newest technologies could be the ones that take over the industry.

7 CONCLUSION

Recently in the media and the cryptocurrency community there has been a lot of attention on the growing energy consumption levels of cryptocurrency mining operations. The topic is very relevant nowadays especially when the whole world is concerned about all the negative impact humanity has had on the environment and all the damage to global ecology by carbon emissions from using fossil fuels. The author of the thesis feels strongly about the importance of researching trends of highly energy dependent industries switching to alternative sources of energy. The author is also intrigued by the subject of cryptocurrencies and their impact on the world. By researching these two subjects the author has helped address a gap in current knowledge and explored a new interesting field.

This research aimed at exploring the phenomenon of sustainable cryptocurrency mining and finding out whether it can be defined as an eco-innovative business model. Through in-depth interviews with experts in the cryptocurrency mining business the researcher managed to obtain first-hand information otherwise unavailable in literature about the specialties of the industry, its strengths, challenges and prospects. This approach combined with the latest information from the existing literature provided a better understanding of how sustainable cryptocurrency mining works and how their business models represent eco-innovativeness in action.

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APPENDIX 1

INTERVIEW QUESTIONS FOR MINING COMPANIES:

BACKGROUND

1. Could you tell me about the background of the company? When was it founded? By whom?
2. Why was it founded? What was the main reason behind it?
3. What is the current situation with the company? Is it growing? Is it facing any problems? Is it stable?

BUSINESS MODEL

4. Why did you choose to use renewables for mining operations?
5. Was it purely ethical reasoning to turn to renewables or was there any market benefit?
6. Is it financially more beneficial to use renewables for your operations?

7. Does the company have to deal with higher production costs due to its sustainable operations?
8. Are the production costs higher than those of other companies in this industry?
9. Are the profits affected by the way the production is implemented? Is it more/less profitable to mine using renewables?

10. Do you think your customers are influenced by the fact that your business is environmentally responsible or because the costs are lower with higher return?
11. What does ABC do differently than other mining centres besides using renewables for mining?

12. How is your company different from other mining centres that rely on renewable energy?
13. Do you think that your company is setting a good example for others?

14. Is there anything else that the company is doing to support sustainability besides the use of renewables?
15. Are there any other innovative changes that your company implements besides using renewables compared to other mining centres?

FUTURE

16. What do you think is the future of cryptocurrency mining in general?
17. Do you think there will be more environmentally/socially responsible mining facilities in the future?
18. Do you think there will be more support from the state to encourage others to go green?
19. How do you envision the future of the company? Do you see any new opportunities on the horizon?

APPENDIX 2

INTERVIEW QUESTIONS FOR RESEARCHERS:

PERSONAL DETAILS

Quick overview of your background and experience in cryptocurrencies. Who you are and what you do?

QUESTIONS ABOUT CRYPTO-MINING COMPANIES THAT USE RENEWABLE ENERGY FOR THEIR MINING OPERATIONS

1. Why do you think some companies are turning to renewables for cryptocurrency mining operations?

    - Do you think it is purely because of ethical reasons or are there any benefits in doing so (e.g. easier to get investments, government support, cutting costs, easier access to energy at certain location)?
    - Do you think is it financially more beneficial to use renewables for such operations?

2. Do you think it is more/less profitable to mine using renewables? If at all different from the mining based on fossil fuel energy.

    - Do you know if the production costs are higher because of the use of renewables?
    - Are the production costs higher than those of other companies in this industry?
    - Are the profits affected by the way the production is implemented?

3. Do you think their investors are influenced by the fact that their business is environmentally responsible or are they only looking for higher returns?

4. Do you think that these companies are encouraging technical innovation for more efficient mining in the future?
5. What do you think is the future of cryptocurrency mining in general? And sustainable crypto-mining in particular?
6. Do you think there will be more environmentally/socially responsible mining facilities in the future?
7. Do you think there will be changes in regulations to support and encourage others to go green?