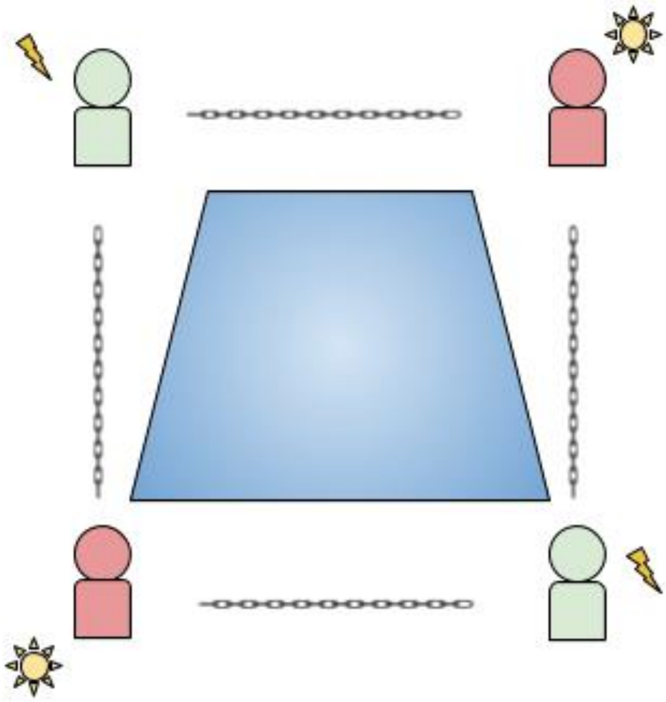
Potential of Integrating Blockchain Technology into Smart City of Stavanger



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STAVANGER

Abstract

Our world today is experiencing a period of intense pressure to make the transition to renewable energies and reduce our footprint on our home planet. The Paris Agreement is one way in which dedication has been made to mitigate climate change and keep our global temperatures at a comfortable level. However, it has been of great importance to continue the search to find solutions that further impact environmental sustainability. With that being said, the purpose and aim of this study is to evaluate the potential of integrating a blockchain based peer-to-peer energy trading platform utilizing microgrids into the Smart City of Stavanger, Norway initiative. This thesis explores the complexities of the innovation and the effect on the adoption process as well as potential barriers that may present themselves through the establishment and operation of such a system. The overall objective is to assess whether Norway, one of the energy hubs of the world, can make such a concept a reality as other countries have only completed pilot projects, proving that the technology works and is effective. The findings of this study were not completely in line with the initial hypothesis, considering even though Norway is very responsive to new innovations, there are a lot of internal struggles as well as regulatory and industrial barriers that will take quite some time to overcome.

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List of Abbreviations

PoW	Proof of Work
PoS	Proof of Stake
PBFT	Practical Byzantine Fault Tolerance
DOI	Diffusion of Innovation
MLP	Multi-Level Perspective
P2P	Peer-to-Peer
BT	Blockchain Technology
kWh	Kilowatt hours
kWp	Kilowatt peak
BMG	Brooklyn Microgrid
PV	Photovoltaic
kV	Kilovolt
DNO	Distribution Network Operator
NVE Directorate	Norwegian Water Resources and Energy

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1. Introduction

Throughout the past few years, the pressure to transition to renewable energy technologies has increased drastically. The amount of greenhouse gases being released into the atmosphere everyday by humans has potentially catastrophic impacts on our planet earth. Especially keeping in mind the establishment of the Paris Agreement, with the expounding goal "to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius" (United Nations, 2015). Henceforth, it is of great importance to push towards finding the most supreme solutions in order to combat such a global issue.

Many countries around the world including Norway, more specifically the city of Stavanger, have begun piloting environmental projects in order to address the issue of climate change and the importance of sustainability head-on. Stavanger, for decades, has been an energy hub of the world due to their abundance of natural resources such as hydropower as well as their sizable access to oil and gas (City of Stavanger, 2016). Being an energy hub of the world, Stavanger has the power to lead, model and test out new ways to find the best possible solution. Their implementation of the *Smart City* is one way in which they are pursuing to do so. One of the Smart City's five priority areas is Energy, Climate and Environment, in which they aim to find technological solutions to "reduce the local greenhouse gas emissions, make it easier for [their] citizens to make climate-friendly choices and adopt more environmentally friendly alternatives for transportation" (City of Stavanger, 2018). These mentioned technological solutions are of great importance to Smart Cities as they *depend* on the development of new technologies in order to progress and ascertain the most efficient and successful solution. One of the potential technological collaborators to a promising solution, with endless opportunities in various sectors of Stavanger Smart City projects, is blockchain technology (Plotnikov, Vardomatskaya & Kuznetsova, 2019). According to Vladmir Plotnikov, Lyudmila Vardomatskaya, and Valentina Kuznetsova, by utilizing the features of blockchain technology, Smart cities will have "opportunities for solving a complex of problems related to: ensuring energy efficiency in buildings, the introduction of sustainable energy technologies for megacities, the formation of eco-friendly settlements…" among a multitude of other advantages (2019). In Smart Cities, the need for collaboration and exchange of various assets and information are of great importance. With that being said, through the implementation of blockchain as a smart city technology, automation and authentication can be achieved at highspeeds. As a result, long processing times of having to go through various different actors, can be shortened. Blockchain technology could be vital for stimulating support and citizen engagement within smart cities, particularly through peer-to-peer energy trading with the utilization of microgrids. Blockchain technology opens a new door for community members to take on a more independent role in their societies regarding individual energy production and consumption as they are able to become active participants in a local energy market. Henceforth, through monetizing and incentivizing smart city opportunities for citizens of Stavanger, blockchain technology may be one of the keys to unlock the value added experience for citizens in the future.

With that being said, this thesis aims to consider and assess the prospect of blockchain technology as a platform for peer-to-peer energy trading in light of innovation literature and smart city trends around the world, while referring to one of the advanced smart cities in Scandinavia, Stavanger, Norway.

1.1 Research Problem

The need to transition to the use of renewable energies on a cosmic scale, aiding in the alteration of the current energy mix today is of great importance. The establishment of the Smart City and the actions it aims to take in attempting to combat climate change and address various issues of energy, climate and environment is very commendable. However, what Smart City is currently lacking, is community involvement with large-scale utilization and production of renewable energies on a local level. Especially in Stavanger, it appears exceptionally attainable and feasible that individuals can make this vision a reality due to the availability of natural resources and the city, as well as the country at whole has a spirited drive for securing environmental sustainability. Stavanger Smart City claims that their purpose is to "strengthen the ability to deal with major societal challenges, develop better and more efficient services for the citizens, and contribute to new business activity and new jobs… [while also] reduc[ing] greenhouse gas emissions, and contribute to a more sustainable community development" (City of Stavanger, 2016). If Smart Cities around the world, such as Stavanger, adopted blockchain technology and used it as a platform to facilitate peer-to-peer energy trading, the community could be more motivated as they reap greater benefits from perhaps the solar panels they already have installed on their roofs, or perhaps will be incentivized to install new renewable production sources at their homes in order to also gain benefits from the new system of energy trading. Those who may not be able to afford such installations will also be incentivized as they will still be able to buy renewable energies as being part of the blockchain network or live in a community or apartment complex where such a network or microgrid is in place. Humans are naturally driven by personal gain, immediacy as well as visible results. Through the use of blockchain technology, it is expected that citizen participation in making the transition to renewables may happen on a larger scale and in a faster time. Citizens would also be able to avoid the costs and long processing times of third-party actors in centralized systems and have more access to affordable, transparent, and equitable renewable energies available in their everyday lives while also incentivizing better energy distribution, better sustainability driven behavior, as well as better practice on the network (Power Ledger, 2019; Harnett et.al., 2018). Stavanger Smart City wants to increase shared responsibility and participation of citizens as well as private industry, and blockchain technology is a potential solution (City of Stavanger, 2016).

1.2 Objective

The objective of this research is to highlight the promising marriage of blockchain technology and microgrids and their ability to facilitate a peer-to-peer energy trading network in the Smart City of Stavanger, establishing a decentralized local energy market.

Plenty of research has been conducted on the benefits that blockchain technology provides to various industries for the sharing and safe-keeping of information and documents such as financial or medical. However, very little has addressed the direct application into smart city projects, enhancing the goal of citizen involvement. Through this research I aim to consider the potential that blockchain holds beyond the sharing of documents and information, but continue the research of blockchains ability to access the energy market and transform it from the traditional, centralized form we have always known and accepted to a decentralized, citizen empowered network. Therefore, through this research, the following research questions will be addressed:

Research Question 1: What factors may affect the adoption process of a new technology with residents of Stavanger?

Research Question 2: What are the potential barriers to establishing and operating a P2P local energy market in Stavanger?

1.3 Outline of the Thesis

This thesis has begun with an introduction to the research of the potential of integrating blockchain technology into Smart City of Stavanger, through addressing the global environmental issue of climate change and the need for an energy transition to renewables on a cosmic scale. The introduction then flows into the research problem and objective in order to set the stage for the study. Subsequently, a literature review will cover the different aspects of blockchain technology, smart contracts, microgrids and the smart city, which I will attempt to explain in a way that is comprehensible to the greater population who has yet to know much about the complex technology. I will address what it is, it's architecture, how it works, types, smart contracts as well as it's current presence in the energy sector. Following the section on blockchain, the literature review will continue onto the topic of smart cities more in-depth where I will address what the concept is, the specific Stavanger Smart city goals, intent and projects followed by the potential of blockchain technology into smart city projects. The next section will highlight the theories I will use to guide and analyze the research focusing on the Diffusion of Innovations theory (DOI) and the Multi-Level Perspective Theory (MLP). An explanation of chosen methodology will follow including data collection methods and analysis. The methodology section will also include the research questions, as well as the research strategy. Next a review of quality in terms of validity and reliability, followed by ethical considerations. I will then analyze two case studies, one being the Brooklyn Microgrid in the United States, and then Quartierstrom in Switzerland, to support the objective of this thesis. Finally, the thesis will enter into discussion and analysis where I will use a theoretical perspective to enhance discovery of the potential of blockchain technology to be implemented into Stavanger Smart City. The thesis will finish with suggestions and conclusions, and then bibliography and the appendix where you will find an averaged out version of the interview guide for the three semi-structured interviews.

2. Literature Review

2.1 What is Blockchain technology ?

Since the turn of the 21st century, the opportunities and capabilities apparent of the technological world seem truly unfathomable and know no limit. Blockchain technology is one of such that has the potential to change the way we live our everyday lives by the means we currently know it. The International Renewable Energy Agency (IRENA), an intergovernmental organization encouraging the development and transition to a future composed of sustainable energy utilization, suggests that blockchain technology has immense applicability to the energy sector and can increase the amount of renewable energy sources into the global energy mix (2019).

Blockchain technology (BT) first made its premiere into the technological world in 2008, alongside the more familiar Bitcoin cryptocurrency (Puthal, Malik, Mohanty, Kougianos & Das, 2018). The debut was on October 31st via a white paper written under the pseudonym Satoshi Nakamoto, while still to this day the true identification has never been revealed (Khatoon, Verma, Southernwood, Massey and Corcoran, 2019). Bitcoin was essentially the first application to utilize the blockchain platform on an extensive level (Fry & Serbera, 2020). Bitcoin differs from other currency transfer platforms such as PayPal, Western Union, and Vipps, due to their lack of financial third party intervention and supervision of transactions between individuals. This form of decentralized, anonymous and immutable currency exchange is only made possible through the complex technological abilities that blockchain encompasses. Bitcoin was just the beginning in terms of what blockchain can actually offer and accomplish in more areas than the financial world.

Over the past few years, blockchain technology has been gaining more and more popularity, attraction and spiking excitement. As previously stated, most people associate blockchain technology with Bitcoin (the digital currency), yet the potential for blockchain promises and entails much more than that. According to Shekar Gupta, blockchain technology could be the key; “a crucial component of what is needed to circumvent outdated systems and build longer-lasting solutions for cities” (2018).

Daniel Drescher, author of *Blockchain Basics : A Non-Technical Introduction in 25 Steps*, expresses that blockchain is still a new concept, therefore one singular definition has yet to be solidified (2017). However, an intermediate definition is that blockchain “is a purely distributed peer-to-peer system of ledgers that utilizes a software unit that consist of an algorithm, which negotiates the informational content of ordered and connected blocks of data together with cryptographic and security technologies in order to achieve and maintain its integrity” (2017). Blockchain technology is a public database that acts as a network of information keeping record of “digital asset transactions using distributed ledgers that are free from control by intermediaries such as banks and governments” (Min, 2019). Through blockchain’s ability to remove expensive intermediaries, leaving interactions to take place between contractual partners, there is shorter processing time as well as reduced costs, thereby increasing the efficiency of the sharing service (Drescher, 2017), reshaping “the world’s most fundamental commercial interactions…[and opening] the door to invent new styles of digital interactions in trust-free sharing services” (Sun, Yan & Zhang, 2016).

This technology has the ability to alleviate the risks that are commonly affiliated with third-party actors such as hacking, political vulnerability, invasion of privacy, heavy governmental costs, volatile financial institutions as well as contract friction (Min, 2019). Some of the features of blockchain that has been gaining the attention of many is that it is transparent, traceable, ensures high security, automatic, private and democratized, decentralized and is trust-free (Saberi, Kouhizadeh, Sarkis & Shen, 2018; Sun, Yang, Zhang, 2016; Hartnett, Henly, Hesse, Hildebrandt, Jentzch, Krämer, MacDonald, Morris, Touati & Trbovich, 2018). The trust that was once in the hands of the reliable third-party actors and central authorities is now dispersed across an entire population of peers who are a part of a “peer-to-peer network” (Sun, Yan, Zhang, 2016).

In a technologically driven world, rapidly developing and proposing new solutions, we are digitizing our daily lives at extreme rates. That being said, more and more of our interactions over time will require less and less intermediaries or third-party actors guiding the process. The potential that technology brings to our daily lives is only going to grow and develop, especially with the growth and adoption of blockchain technologies. Those already reaping the benefits and efficiencies of blockchain and peer-to-peer systems suggest that "almost all aspects of our life will be affected by the emergence of digitalization and peer-to-peer networks, such as payments, money saving, loans, insurance, as well as issuance and validation of birth certificates, driving licenses, passports, identity cards, educational certificates, and patents and labor contracts" (Drescher, 2017) The potential for blockchain technology is only growing and developing and moving into more and more aspects of our daily lives.

2.1.1. Characteristics of Blockchain Technology

The blockchain system encompasses four key characteristics. These characteristics are decentralisation, persistency, anonymity, and auditability (Zheng, Xie, Dai, Chen and Wang, 2018). The decentralisation characteristic of blockchain is its ability to remove the central authority (e.g., banks) which traditionally result in additional costs and potentially act as a system bottleneck (Zheng, Xie, Dai, Chen and Wang, 2018). Juxtaposing to the traditional central authorities, blockchain technology enables two peers (peer-to-peer transactions) to validate and authenticate transactions safely on their own. By conducting transactions this way, "blockchain can significantly reduce the server costs (including the development cost and the operation cost) and mitigate the performance bottlenecks at the central server" (Zheng, Xie, Dai, Chen and Wang, 2018). In addition, the possibility of loss of information is drastically lowered because there is no single point of failure considering the complete ledger of information is distributed to all of the network participants (Puthal, Malik, Mohanty, Kougianos and Yang, 2018).

Persistency in regards to blockchain technology refers to the tamperability of the system. Due to the technology broadcasting of all transactions to the entire network for confirmation and validation, it is very difficult, if not approaching impossible to tamper with. The user nodes on the network are responsible for checking these transactions and following a predetermined and agreed upon consensus mechanism/ algorithm in order to maintain the safety and tamper-proof characteristics of the system. Therefore, if there were any sort of malicious players or actions, it would be easily detected by the network (Zheng, Xie, Dai, Chen and Wang, 2018).

Anonymity is the third characteristic of blockchain technology. According to Zheng, Xie, Dai, Chen and Wang, blockchain technology has the ability to provide complete anonymity of its users through the generation of an address or multiple addresses, to ensure that the identity and personal information of the user is kept private (2018).

Auditability is another important characteristic of the blockchain. This characteristic refers to the ability to "easily verify and trace the previous records through accessing any node in the distributed network" (Zheng, Xie, Dai, Chen and Wang, 2018). This means that any user on the network is able to see the history of any given transactions and how it has been dealt with by the network. This ensures that the network remains transparent and all data, although anonymous, is visible to members.

2.1.2. Types of Blockchain Technology

Blockchain technology systems can ultimately be classified into one of three different categories: public, private, or consortium.

A public blockchain (permissionless) is a system of blockchain where the platform is open to anyone and everyone who wants to be a part of it. There are no restrictions in regards to who can join, make transactions, verify transactions, mine, view transaction histories, review etc., whenever they would like, therefore, the system is permissionless (Puthal, Malik, Mohanty, Kougianos and Das, 2018). The copy of the ledger is available to everyone on the network, reinforcing blockchains traits of transparency, therefore it is of utmost importance that a distributed consensus mechanism is enforced as there is most likely no existing trust between the nodes in the system (Jesus, Chicarino, Albuquerque and Rocha, 2018). This is where proof-of-work or proof-of-stake becomes very important and necessary in order to authenticate and dispose of invalid requests or malicious activity. However, with the combination of consensus mechanisms and blockchain's cryptography security features, it is extremely difficult for anything to actually go wrong on the platform (Puthal, Malik, Mohanty, Kougianos and Das, 2018).

In contrast to to a public blockchain system, a private blockchain (permissioned) means that the system's participation and membership is not open to everyone. Instead, in order for someone to become a part of this particular blockchain system, they need to be invited, preselected or be approved access (Puthal, Malik, Mohanty, Kougianos and Das, 2018). According to Puthal, Malik, Mohanty, Kougianos and Das, this category is "set up to facilitate the private sharing and exchange of data among a group of individuals (in a single organization) or among multiple organizations, with mining controlled by one organization or selected individuals" (2018). This means that all members of the network are known and have been specifically granted access to the network. With that being said, there is already a certain level of trust considering it is not someone completely anonymous from another corner of the world for example. Not just anyone can join. In this permissioned system of blockchain, the responsibility of the selected nodes is to "contribute in running a decentralized network, with each node maintaining a copy of the ledger and collaborating to reach a consensus for updating" (Puthal, Malik, Mohanty, Kougianos and Das, 2018). When utilizing a private blockchain, the process of verification and authentication is much simpler than that of a public blockchain. That is because the network is already composed of trusted nodes, therefore the processing of transactions is faster and does not require as many nodes or as much computing power to ensure a proper consensus (Jesus, Chicarino, Albuquerque and Rocha, 2018).

Consortium is another category of blockchain being a combination of both private and public. This means that "no single organization is responsible for consensus and block validation but rather a set of predetermined nodes" who are responsible for deciding who can and cannot join and mine on the network (Puthal, Malik, Mohanty, Kougianos and Das, 2018). This type of blockchain is most popular amongst companies or institutions within the same industry wanting to work together in some way and for example, exchange information with one another or carry out transactions on a common ground (Binance Academy, n.d.). In a consortium blockchain, as long as members of the network agree on a set of rules for the blockchain, such as who can read and write on the blockchain, different forms and levels of public or private can be applied based on what works best for the particular network (Puthal, Malik, Mohanty, Kougianos and Das, 2018).

Property	*Public blockchain*	*Consortium blockchain*	*Private blockchain*
Consensus determination	All miners	Selected set of nodes	One organisation
Read permission	Public	Could be public or restricted	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Centralised	No	Partial	Yes
Consensus process	Permissionless	Permissioned	Permissioned

Table 1: *Comparison of blockchain types (Zheng, Xie, Dai, Chen and Wang, 2018).*

2.2. How does blockchain technology work?

Blockchain technology ultimately acts as a platform for the first decentralized, immutable, transparent and cryptographically secure form of information exchange and sharing. Traditionally, systems of information or money exchange include an intermediary such as a bank or some sort of central authority supervising and monitoring all forms of transactions as well as taking a fee for the work they have done. However, with blockchain technology, that intermediary is removed and is instead run by network participants dispersed throughout various locations, through a computer or smart device with access to the internet.

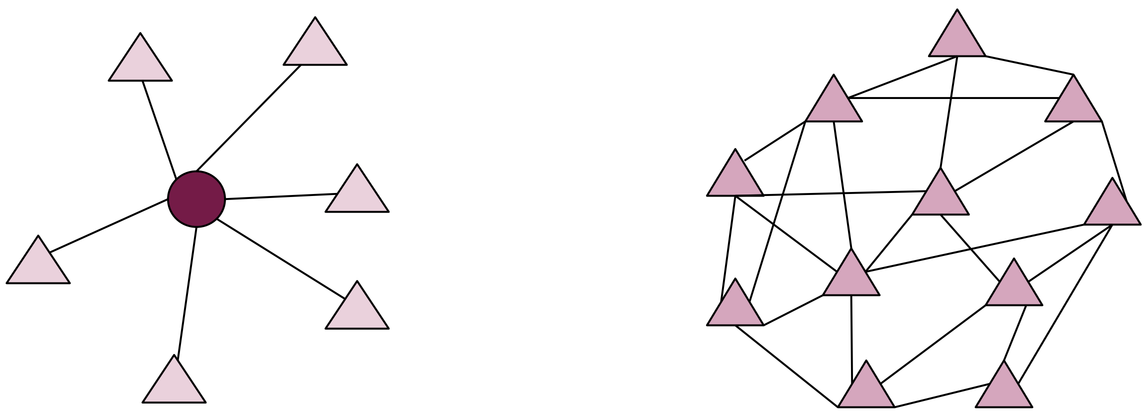

Figure 1: *A traditional centralised system encompassing a "trusted intermediary" (left) versus a decentralised blockchain system (right).*

Over time, as more specialists have begun to explore and test the limits of blockchain technology, the potential it encompasses across many different industries has shown great promises and excitement, especially in the energy sector through peer-to-peer energy transactions. To be concise, blockchain technology is a way to store, organize and share data (Markelevich, 2018). It is a public distributed ledger, comparable to a database if you will, that logs and records all transactions made on an established network of participants in chronological order, while also ensuring security and complete immutability.

There are currently three different applications of blockchain that have been defined in regards to how far the technology has come and its technological capabilities. These categories of evolution are Blockchain 1.0, Blockchain 2.0 and Blockchain 3.0 (Gatteschi, Lamberti, Demartini, Pranteda, and Santamaria, 2018). Blockchain 1.0 was the first presentation of blockchain technology which correlates most strongly to cryptocurrencies such as Bitcoin as well as other monetary applications (Gatteschi et.al., (2018). It is ultimately the phase defined by money. Blockchain 2.0 follows with its main focus on "registering, confirming and transferring contracts or properties"(Gatteschi et.al., (2018). Blockchain 2.0 gave way to the concept of smart contracts which are "pieces of code stored on the blockchain...programmed to behave in a certain manner when certain conditions are met" (Gatteschi et.al., (2018). Smart contracts will be discussed in greater detail in a later section.

Finally, Blockchain 3.0 opened their doors to more than just transactions of finance and goods, but also to sectors such as government, academics, science, healthcare, as well opportunities of application to many Gatteschi et.al., (2018)

Before the explanation of how blockchain technology actually operates, it is first important to understand the structure of the blockchain and the way it is formed. According to Gatteschi et.al., (2018), blockchain technology can be thought of as a continuously growing strand of DNA (2018). Transactions or records that are made and exchanged between users on the blockchain network create the individual blocks.

There are three main components of an ordinary block:

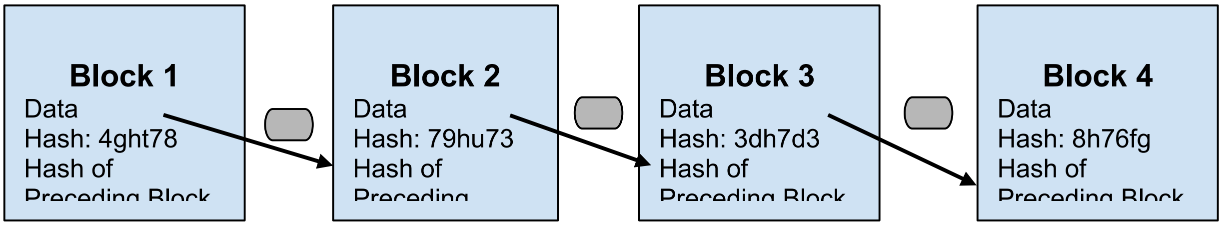

Figure 2: *Architecture of a general block on the blockchain*

1. Data: Information regarding the transaction (ex. the value of what is being shared and information regarding the sender and receiver).
2. Hash of the Block: A cryptographic function that mathematically "maps a given set of data to a fixed-size sequence of symbols" Gatteschi et.al., (2018)
3. Hash of the Preceding Block: A cryptographic hash ID of the block prior.

Each transaction or exchange of information forms one new block which is organized on the chain in a sequential order (time-stamped), linked to the blocks prior to them Gatteschi et.al., (2018). When the very first transaction is made and a block is created, there is obviously no existing prior block with a cryptographic hash that can be recorded. This block is called the "genesis block" (Nofer, Gomber, Hinz and Schiereck, 2017).

As more and more transactions are made between users or "nodes" on the network, the blockchain grows in length and "represents a complete ledger of the transaction history" (Nofer, Gomber, Hinz and Schiereck, 2017).

Here is how the technology works:

First, a group of computers with access to the internet establish the blockchain network. These individual computers and users are referred to as "nodes". Considering the blockchain is a decentralised system, these nodes all hold the same amount of power and authority over each other leaving "their computational resources (e.g., processing power, storage capacity, data or network bandwidth) directly available to all other members of the network without having any central point of coordination" (Drescher, 2017). In addition, they obtain the same roles and responsibilities within the operation and ownership of the network (Markelevich, 2018). Each individual member and respectful connected ‘node’, is equal in terms of their position and rights within the blockchain system (Drescher, 2017). Transactions between these given nodes in the system are considered the “blocks” which then as more transactions occur, will join together to create the chain portion of the blockchain.

When a node wants to make a transaction or exchange, they will first transmit a message into the network “which contains information on the value of the transaction and a digital signature that confirms the authenticity of the sender, transaction and the receivers address” (Burger, Weinmann, Kuhlmann, and Richard, 2016). This is the “data” component of the block and the original hash ID. According to Puthal, Malik, Mohanty, Kouglianos and Das, the transaction should never happen directly between the sender and the receiver, rather transmitted to the whole network to be validated and approved for authenticity and security purposes (2018). Upon receiving the broadcast, the other members of the network then authenticate the validity of the message broadcasted and verify it through decryption of the digital signature (Burger, Weinmann, Kuhlmann, and Richard, 2016). Decryption is ultimately the opposite of encryption. With that being said, to suggest that something is encrypted means that it has been translated into a random form of code that is very difficult to guess or manipulate. Hence, decryption would then be the reversal of the random code, converting it back to its original form. This process works through the utilization of public and private keys, to ensure a secure operation. Each user on the network has their own set of public and private keys. The user's private key is used to sign a transaction by its owner of the funds, while the public keys can be thought of as a kind of address which is open to all members of the network (Zheng, Xie, Dai, Chen and Wang, 2018). For example, in a scenario provided by Zheng et.al, a user called Alice wants to make a transaction and therefore has to sign it in order to be verified (give it a digital signature). First, she has to generate a hash value derived from the transaction which she then encrypts through the use of her private key. By doing this, she is in a way creating a complicated password for her transaction so that no one with malicious intentions can access, or tamper with it. She then sends this encrypted hash to the network for verification. Other nodes on the network verify the transaction by decrypting the hash that Alice has sent using her public key. The receiver does this by comparing the “decrypted hash (by using Alice’s public key) and the value derived from the received data by the same hash function as Alice’s” (Zheng, Xie, Dai, Chen and Wang, 2018). See figure below.

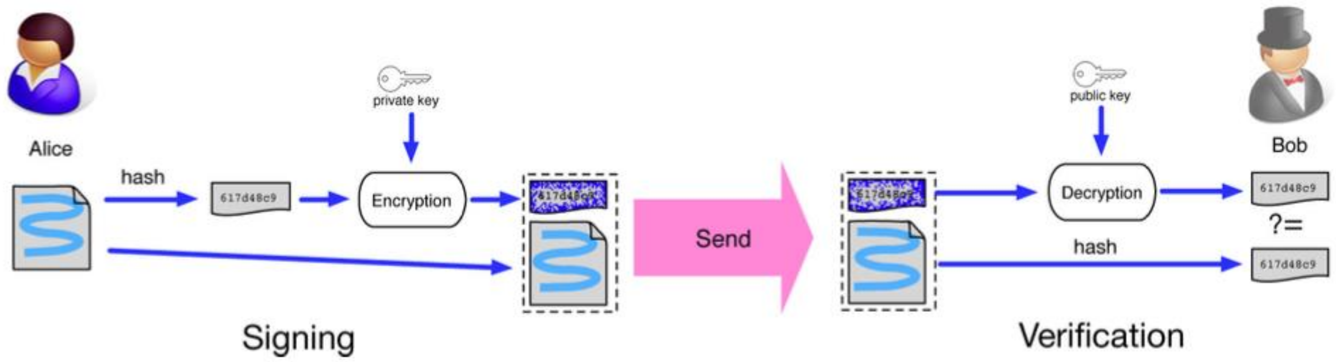

Figure 3: *Digital signature process using public and private keys between nodes on a blockchain network (Zheng, Xie, Dai, Chen and Wang, 2018).*

It is of great importance that the private key is kept secret. If someone were to find out the private key, they could access their money and personal data.

Once the transaction is verified by the majority of the network nodes, the transaction will be placed in a block integrated into the blockchain and presented to the network as a representation of the new state of the ledger (Burger, Weinmann, Kuhlmann, and Richard, 2016) If the transaction is not verified by majority of the network users, the transaction will be thrown out.

2.2.1.Consensus Mechanisms

It is also important to acknowledge that the blockchain system operates through a means of consensus. This means that due to there being no central authority making sure all transactions and interactions between users are done responsibly, ensuring information is securely stored and accountability for security breaches are dealt with appropriately, it is up to the network members to carry out these roles and responsibilities based on a consensus of how they want to confirm or discard blocks and transactions (Puthal, Malik, Mohanty, Kougianos and Das, 2018; Puthal, Malik, Mohanty, Kougianos and Yang, 2018). This can be done through different types of consensus mechanisms such as the proof-of-work protocol (PoW), proof-of-stake protocol (PoS), or the practical Byzantine fault tolerance protocol (PBFT) (Puthal, Malik, Mohanty, Kougianos and Das, 2018). Different entities have begun creating their own forms of consensus protocol, however, for the simplicity of this study, I will be focusing on these three protocols. The consensus mechanisms are extremely important for the blockchain system as it provides greater security and stability for the network to operate on. According to Jesus, Chicarino, Albuquerque and Rocha, a consensus mechanism needs to be secure, and in order to be secure, the nodes must always be able to produce the same valid results as well as encompass fault tolerance, or in other words, the "ability to continue to operate and reach consensus, correctly, even after the failure of some network nodes" (2018). If a consensus mechanism can promise these elements, then it can be used to secure a blockchain network.

According to Puthal, Malik, Mohanty, Kougianos and Das, proof-of-work (PoW) was the first consensus protocol and was also created and employed by Satoshi Nakamoto to secure his bitcoin network (2018). PoW utilizes a system called mining where the network users are incentivised (through reward such as a token system) to compete against each other to calculate the value of the next block (Puthal, Malik, Mohanty, Kougianos and Das, 2018). This process can be thought of as trying to solve a mathematical equation or puzzle. Jesus, Chicarino, Albuquerque and Rocha describe the proof of work process as follows: "the sender adds an arbitrary number to the message (called a nonce) and applies a mathematical hash function to the message...the goal is to find an answer with a number of advanced zeros that meets the network's current difficulty target…" (2018). The sender continues to replicate this process over and over again by changing the nonce number until the correct answer is found. Once the member nodes find the solution or the next hash value, the other nodes then have to have it confirmed by other nodes before it can be added to the established blockchain (Puthal, Malik, Mohanty, Kougianos and Das, 2018). Considering this process is relatively difficult to complete, "upon receiving the message, every user will be able to verify that there has been a great effort by the sender to generate it" (Jesus, Chicarino, Albuquerque and Rocha, 2018). In order for a malevolent block to make its way onto the blockchain, there would have to be a single computer that has control and power greater than 51% of the entire network, which is incredibly unsustainable (Puthal, Malik, Mohanty, Kougianos and Yang, 2018). Henceforth, the immutability of the technology is sustained.

A downfall to this type of consensus mechanism is that it utilizes a large amount of computing power as many individual nodes are working to find the solution (Puthal, Malik, Mohanty, Kougianos and Das, 2018). With that disadvantage in mind, came the formulation of the proof-of-stake consensus protocol.

As previously stated, the proof-of-stake (PoS) protocol was designed to give an alternative to the high computational power required of PoW. Jesus, Chicarino, Albuquerque and Rocha illustrate PoS as a mechanism that “depends on a validators stake in the network” (2018). PoS is different from PoW because there is no competition between network nodes. Instead, a block creator is chosen randomly through a system algorithm according to their stake in the network (Jesus, Chicarino, Albuquerque and Rocha, 2018). Each block created validly leads to the node being incentivised, however, if there are blocks that are not valid and therefore not added to the blockchain, they are decentivised by losing some of their stake (Puthal, Malik, Mohanty, Kougianos and Das, 2018). Just like PoW, PoS requires over half of the network to be controlled by a hacker in order for malicious activity to occur on the blockchain.

Lastly, the Practical Byzantine Fault Tolerance algorithm (PBFT). This consensus mechanism stems from the Byzantine Generals’ Problem, where the Byzantine army needed a solution to conduct a successful attack on their rival city (Puthal, Malik, Mohanty, Kougianos and Das, 2018). According to Puthal, Malik, Mohanty, Kougianos and Das, in order to achieve a successful conclusion, the army needed to attack using the same predetermined plan concurrently, and “no matter what the traitors do, the loyal generals should stick to the decided plan, as a small number of traitors could ruin the plan” (2018). Unlike PoW or PoS, PBFT requires the know of how many nodes are partaking in the network, therefore, this type of consensus mechanism is only effective with private blockchains (Jesus, Chicarino, Albuquerque and Rocha, 2018).

PBFT applies to blockchain technology as a consensus mechanism for this reason: the nodes on the blockchain network can be thought of as the army. The member participants (nodes) on the network ”maintain their current state, and, when a new message is received, the current state and the message are fed together for computations to help the node reach a decision” (Puthal, Malik, Mohanty, Kougianos and Das, 2018). The decisions are then broadcasted to the rest of the nodes on the network and the majority of the decisions is what establishes the consensus (Puthal, Malik, Mohanty, Kougianos and Das, 2018). To explain on a more technical playing field, PBFT operates with the confidence that "...blockchain nodes can tolerate faulty nodes up to □, where □ is a known arbitrary fraction of the total number of nodes…" (Jesus, Chicarino, Albuquerque and Rocha, 2018). In an attempt to explain simply, first a node or "client" wishing to perform a transaction will send a service request to the primary. The primary node is randomly selected for each consensus case. The other nodes in the system are then considered the replica nodes or "back-up" nodes. The primary node is responsible for replicating the request sent by the client to the replica nodes to carry out the request and respond (Jesus, Chicarino, Albuquerque and Rocha, 2018). The majority decision of the network replica nodes determines the consensus for the request (Puthal, Malik, Mohanty, Kougianos and Das, 2018).

2.3. Smart Contracts

As blockchain technology continued to gain more popularity and more research was conducted on it's abilities, smart contracts were one addition that came along in blockchain 2.0, further propelling the technology and gaining attention in various different sectors for its attractiveness. Smart contracts were originally introduced by Nick Szabo in the mid 1990's, as he discovered that blockchain technology encompassed an environment that could facilitate and execute contracts on its own (Nofer, Gomber, Hinz, Schiereck, 2017). Blockchain technology is still relatively new to many, therefore the technology that existed over twenty years ago when Szabo presented smart contracts, was not up to par in comparison to what it is today. With that being said, smart contracts are now in a position with blockchain technology where they can cooperate with much more ease.

According to Gatteschi et.al., "smart contracts are pieces of code stored on the blockchain that are programmed to behave in a given manner when certain conditions are met" automatically without the need for intervention, control or over-see from a trusted intermediary (2018). For example in the context of peer-to-peer energy trading, when Lucy receives 'X' kWh, then James automatically will receive 'Y' currency units in return (IRENA, 2019). Again, this contractual agreement is implemented and carried out without the interference or help of another third party actor. Many researchers also allude smart contracts to the alikeness of a vending machine. The vending machine acts as the ledger, and the products inside the machine are anything from kWh of renewable energy to written wills (IRENA, 2019). When the item is purchased, the product is dispensed as soon as the payment is received and the selection is made. It is through this process that smart contracts work on an "if-then" premise (IRENA, 2019).

For the sake of this research paper, I will use P2P energy trading as a reference point for smart contracts. Under this frame of reference, the smart contracts role is " to ensure that the requested type and amount of energy is transferred to the buyer and the seller gets the equivalent payment on time" (Jogunola, Hammoudeh, Adebisi, and Anoh, 2019). It is important when using blockchain to buy and sell energy amongst peers that a set of rules and regulations are established in order to govern the network members interactions such as how to pay for their bought or sold electricity, time of trades, who can be involved, etc, to avoid conflict and hold accountability when necessary (Jogunola, Hammoudeh, Adebisi, and Anoh, 2019). The smart contract allows for these rules and regulations to be digitally agreed upon by all involved members just like a real contract created by a legal actor. However, unlike using an actual legal actor, the blockchain enables costs of paying a third party to be avoided, as well as the needed trust that comes along with incorporating an intermediary. According to Nofer et.al., such an innovative approach being applied to blockchain technology threatens more industries such as the legal and financial lawyers and bankers as their positions may also become obsolete given if blockchain technology and smart contracts become widely accepted and adopted in the future (2017).

When paired alongside blockchain technology, smart contracts present various advantages. These advantages of smart contracts are: accuracy, transparency, speed and efficiency, security and cost reduction (Allam, 2018).

It is extremely important that the smart contract is as accurate as possible, especially because most transactions between individuals on the blockchain network will require some sort of exchange of a monetary value. With that being said, the smart contracts must enforce and format the if-then premise very explicitly in order to avoid transaction errors (Allam, 2018). Extreme accuracy is very attainable on the blockchain platform because once something is created and added, it cannot be altered or tampered with. Due to this, "the automation exhibit in the smart contracts avoids most of the issues that are found in the traditional contracts" (Allam, 2018). Zaheer Allam claims that issues such as breach of contract, delays in signatures as well as disputes can be heavily reduced with the implementation of smart contracts with special attention to the regulation accuracy that smart contracts can provide (2018).

Transparency is another positive trait attained by smart contracts. As stated in previous sections, information on the blockchain is available and open to all network participants. The same then goes for the smart contract. The smart contract ensures that every detail is brought to the forefront and under the spotlight for everyone to see. The same copy of the contract is visible to everyone on the network, therefore reducing the risk of being swindled by organizations or other actors (Allam, 2018). For example, if someone on the network tried to overcharge another node on the network for some kilowatts of electricity, the transaction wouldn't be able to go through because the contract is not set up reflecting such amounts in regards to their “if-then” premise. If smart contracts are utilized challenges regarding deception or breaches are avoided.

Speed and efficiency is another commendable advantage of smart contracts. Smart contracts again, do not rely on intervention of a third party unlike the traditional form of contracts which use some sort of legal entity governing the process. Instead, smart contracts are self-executed in response to a trigger event such as a time, date, or a task initiated by a member of the network (Allam, 2018). For example, a certain amount of monetary units being transferred from a consumer to the producer of the electricity. According to Allam, once the contract has been triggered, self-execution begins and “ the verification of whether the correct amount has been paid, and there if the correct subsection, service and associated aspects ...is determined by the nodes in the blockchain network” who are all familiar and have access to the agreed upon contract (2018). Therefore, the result is then fast, resilient and robust (Allam, 2018).

In terms of security, smart contracts have one of the highest forms of security measures (Allam, 2018). Being stored on the blockchain, all the security features (cryptography) and methods used then apply to the smart contract. The nodes on the network are all part of the “non-trusting” environment that requires them to validate each other to “ensure each transaction is carried out effectively, and that there is a uniform world view of the status of all the transactions” (Allam, 2018). Therefore, the smart contract concept is very secure.

Finally cost reduction. Cost reduction is an advantage for smart contracts especially in addition to the cost benefits of using blockchain technology. As previously mentioned, smart contracts eliminate the need for the intermediary such as a legal personnel, "reducing the overall organizational costs and maximizing the profit margins by an organization" (Allam, 2018). However, this means that without the professional legal entity taking care of the contract, it is only as good as the input into the system for the contract. It is important to make sure the contract is of quality in order to avoid problems within the system (Allam, 2018).

2.3.1. Challenges/ Disadvantages of Smart Contracts:

Even though there are many advantages to the utilization of smart contracts in a blockchain technology system, there are also a few potential drawbacks or limitations that some may experience. These potential challenges are immutability, systemic risk, and legal adjudications and enforceability (Allam, 2018; Lee and Khan, 2020).

Immutability previously was contextualized in a positive manner as a trait of blockchain. However, since the smart contract is then stored on the blockchain it also then takes on the characteristics of blockchain and in turn becomes immutable which can propose some challenges in the contractual realm of things. Traditionally, contracts generally are able to be changed or made amendments to. However, once a smart contract is established and implemented on the blockchain it is not to be altered and can be very difficult to make any changes to. With that being said, there are a few things that creators of the smart contract can add to the contract before it is implemented to prepare for certain scenarios that may present themselves such as some sort of "escape hatch" to be included in the coding of the contract (Allam, 2018). It is difficult to anticipate what kind of alterations may need to be made to a contract before it is in effect, but given the complexity of the environment and what needs to be contractually agreed upon, will vary from case to case. The immutability trait of smart contracts highlights the importance of a trusted computer programmer to ensure that proper and skilled coding is carried out. A smart contract is only as good as the coding skill behind it. With that being said, if the smart contract is not properly engineered and implemented, there can be many faults to the system. The more complex the contract needs to be, the more difficult it will be to code it effectively.

In addition, systemic risk is a challenge that may be experienced through use of smart contracts. According to Lee and Khan, mistakes or inclarities in the coding of a smart contract can lead to a "systematic chain reaction of error" which could lead to multiple problems for the software as well as the individual parties involved such as "incorrect billing, malfunctions between transactions and loss of potential or purchased energy units" (2020). One of the underlying issues with this is that if there is an error in coding, the software can potentially still operate without giving much sign that something has gone wrong, leading to the incorrect operation of the entire system (Lee and Khan, 2020). This challenge, however, is avoidable given if coding is done properly and kept simple, referring back to the importance of trusted computer programmers.

Another risk that could be experienced through the utilization of smart contracts on a blockchain platform is legal adjudications and enforceability. Legal enforceability of the smart contract is still relatively new and developing. Considering a traditional contract is in writing, can be amended and is very familiar to legal actors, it is much easier to enforce on a legal level. However, the smart contract is written in code which can be difficult and unfamiliar still to many legal entities. Therefore, according to Allam, it is necessary moving forward for a "translation of the legal framework governing the contracts into the software logic to ensure that besides the contract being self-executing, they also adhere to the legal regulations of formal contracts" (2018). Regardless, as smart contracts have continued to be implemented and piloted in various different industries under different regulations and complexities, the amount of contract breaches or difficulty of enforcement is very low. This is considering the contract is self-executing on an if-then premis, being triggered by actions that no members of the network can actually control (Allam, 2018). For example, if someone requests 10 kWh of electricity but the seller does not receive the payment, the contract will not execute the release of the electricity, therefore the contract will not be able to be breached. As time goes on, more and more legal entities are becoming more familiar with smart contracts and developing and incorporating their new role in various industries.

2.4 Microgrids

When it comes to P2P energy trading over a blockchain platform, microgrids become especially important. According to the United States Department of Energy, a microgrid "is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously" (Lantero, 2014). However, microgrids normally operate while connected to the main utility grid, but can be switched and disconnected at a simple flip of a switch (or automatically) in the event of an emergency or event of some sort where ‘island mode’ would be beneficial to the community (Lantero, 2014). The way a microgrid is connected to the main grid is at a coupling point that sustains the same voltage as the traditional grid (Lantero, 2014).

Independently controlled microgrid technology can be powered by various sources of energy such as batteries, solar PV, wind, generators, natural gas-fueled turbines, fuel cells, allowing for a wide array of consumers and prosumers to utilize it’s opportunities (Karandikar, Chakravorty, Rong, 2019; Vine and Morsch, 2017). The opportunities that microgrids possess is the ability to provide lower grid associated costs, access to electricity given an blackout due to weather or repairs, enhanced individual control over society members' own energy as well as the ability to connect and utilize a local resource that is too small or unstable for the main utility grid to apply (Karandikar, Chakravorty, Rong, 2019; Lantero, 2014). In addition, microgrids are important enablers of P2P energy trading systems as they bring “infrastructures and technologies in the domains of monitoring, communication and control” (Sousa, Soares, Pinson, Moret, Baroche, Sorin, 2019).

Such technology can aid in increasing city resilience, reducing emissions, as well as achieving various global sustainability goals including the implementation of smart cities “which strive to create safe, liveable communities with thriving economies” (Vine & Morch, 2017). However, at this day in age, current regulations do not allow for microgrids to be operated or established by anyone other than the utility companies (Vine & Morsch, 2017). According to Vine and Morsch, this is due to concerns on the investor side of the projects regarding regulations and market rules, electrical codes, local ordinances, tariffs, as well as the overall environment that the microgrid will operate in (2017).

With that being said, like blockchain technology, microgrid awareness and understanding is quite immature and the potential that they offer as well as where they fit into the painted picture of the future is still concealed to many. Therefore, the adaptation of laws and regulations are hesitant to make changes. Accordingly, research suggests that local and state governments should begin to make way and support emerging technologies through the establishment of development incentives, eliminating policy barriers and delving into the discovery of the potential that microgrids offer to our societies (Vine and Morsch, 2017).

2.5. The Smart City

2.5.1. What is a Smart City?

At present, our population is at an extraordinary 7.7 billion people, and is expected to grow to 11.2 billion by 2100 (United Nations, 2017). The University of Stavanger Smart City research team suggests that at this point in time over half of the global population is residing in urban areas, and with the growing inhabitant numbers, this statistic is only rising, leaving "energy consumption and CO2 emissions [to grow] in parallel with the growth of the world's cities" (2019). These cities only take up "4% of the Earth's surface, but consume 67% of energy and account for 70% of greenhouse gas emissions (Macke, Casagrande, Sarate & Silva, 2018). With that being said, the demand for resources is dramatically increasing and more space is needed to better acquire all of the world's new occupants.

At a place in time where we are already on the hot-seat to meet climate change goals and assist in mitigating greenhouse gas emissions, the challenge continues to persist and only gets more difficult to decelerate. Therefore, projects such as Smart City are working to address such global issues. According to the City of Stavanger (Stavanger Kommune), " a smart city is based on the citizen's needs and applies new technology to make the city a better place to live, reside and work…" (2018) including creating such cities which "utilise resources better, be energy-efficient and have smart solutions for homes, buildings and infrastructure" (University of Stavanger, 2019). The Smart City concept was initially embraced by countries in the European Union, however, nowadays Smart City developments can be found all over the globe, each working to accomplish "smarter" city management techniques and solutions (Corte, D'Andrea, Savastano, & Zamparelli, 2017).

Technology is really the driving force behind Smart Cities as these project cities do in hindsight come to be "smarter". He, Stojmenovic, Liu and Gu, further highlight this technological importance stating that smart cities rely "on the widely distributed smart devices to monitor the urban environment in real-time, to react in time, to establish automated control, to collect information for intelligent decision making, and to facilitate various services and improve the quality of urban living" (2014). One of the important features of Smart cities is human involvement and participation. Smart City ultimately serves as the platform for both technologies and human capabilities to interact and progress seamlessly (Corte, D'Andrea, Savastano & Zamparelli, 2017).

All countries around the world are different and require different solutions based on their needs and challenges. Smart cities are able to be shaped and customized to each individual city in order to most effectively achieve personalized goals. Some of the features that smart city projects around the world can provide are smart parking management, electric vehicle charging stations, smart street lighting, city bikes or scooters, smart directional signs, smart waste collection, robots, virtual traffic managers, amongst a multitude of others (Amsterdam Smart City, 2016).

2.5.2. Stavanger Smart City

As previously specified, Stavanger, Norway, is one of the energy hubs of the globe, already ahead of most of the world in terms of making smart-decisions and taking action to combat and mitigate climate change especially through the utilization of renewable energies. Stavanger adopted the Smart City project on December 12th, 2016, in hopes to "find smarter and more efficient solutions to important societal challenges" (City of Stavanger, 2016). The Stavanger Kommune illuminates global issues regarding the need to develop more sustainable practices however additionally highlights that they "have regional challenges...that require innovative thinking- as a result of the recession in the oil and gas industry" (City of Stavanger, 2018).

This particular Smart City project's purpose and personalized goals intend to 'strengthen the ability to deal with major societal challenges, develop better and more efficient services for the citizens, and to contribute to new business activity [creating] new jobs, while also reducing greenhouse gas emissions, and contribute to a more sustainable community development' (City of Stavanger, 2016). These personalized goals can be reflected through the five priority areas of choice being health and welfare, education and knowledge, energy, climate and environment, urban art, and governance and democracy (City of Stavanger, 2016).

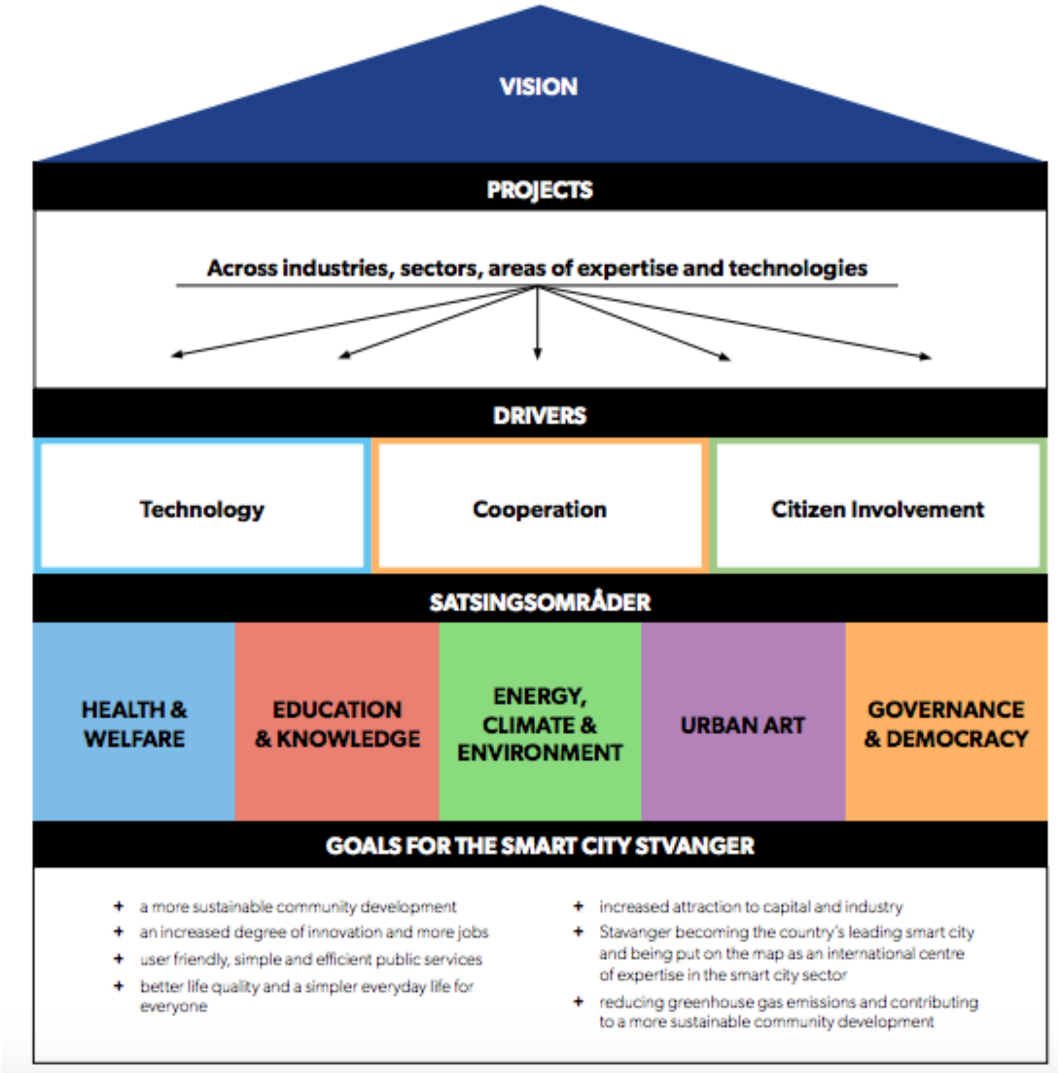

Figure 4. *Illustration of the Smart City Stavanger.*

Taken from Roadmap for the Smart City Stavanger: Vision, goals and priority areas document.

The Stavanger Kommune is currently engaging in many different smart city projects, some being already implemented while others are still in the piloting and research phases. These projects include, electrical vehicle charging lamp posts, AV1-robots for long-term sick children, LoRaWAN sensory network and smart waste management, digitisation of parking, sensor controlled weed control, mobility points to find various modes of transport, digital directional signs, sustainable tourism within the cruise industry amongst various others (City of Stavanger, 2018; City of Stavanger 2016). One project that is rather new and still in progress that is most relevant to the concept of peer-to-peer energy trading is CityZEN- Center for Digital Urban Community Living. CityZEN is a project that the smart city team at the kommune is working on in collaboration with the University of Stavanger (head of the application) as well as other industries that is based on blockchain technology and smart contracts (Stavanger Kommune, n.d.). The goal of this smart city project is to "develop data-sharing solutions in applications that make the lives of residents easier, while protecting privacy" (University of Stavanger, 2020). This project shows that the Stavanger Smart City projects have already begun to gain interest in the application of blockchain technology and smart contracts.

Each of these projects going on in Stavanger require "cooperation and interaction across the usual dividing lines in a community" encouraging citizens to "participate in innovative projects and become more involved in decision-making" (City of Stavanger, 2016). Stavanger has taken opportunities that come along with the Smart City very seriously and are making very progressive actions to achieve their goals. However, as will be discussed later on, the implementation of peer-to-peer energy sharing and trading has the potential to take Smart City projects to the next level and make an extreme influence on both the regional as well as global scale.

2.5.3. Potential of integrating blockchain technology into Stavanger Smart City Projects

As previously discussed, the issue of climate change and carbon emissions on a global level is reaching a height of great importance and calling for immediate action. With goals set, such as the Paris Agreement's goal to reduce emissions by 2030 (United Nations, 2015), there is no one solution that is going to be able to combat climate change and achieve such ambitious goals on it's own with such a restrictive time frame. In the scientific realm of research, much has been explored and published in regards to potential benefits that blockchain technology can have for various industries. However, one of the industries that has recently been given great attention to that could dramatically benefit from blockchain is the energy sector. That being said, by incorporating blockchain technology and microgrids into the Smart City projects around the world, the promotion and utilization of renewable energies may be further enhanced, advancing us closer to meeting crucial goals for the survival of our home planet through the transformation of current energy markets.

As mentioned at the beginning of this literature review, with Stavanger being the Smart City project of research focus, one of their most prominent priority areas they wish to address in their community is Energy, Climate and Environment, wherein the goal is to "reduc[e] greenhouse gas emissions, and contribute to a more sustainable community development" (City of Stavanger, 2016). Contributors of The Energy Web Foundation confidently claim that blockchain has the ability to speed up "the global transition to a decentralized, democratized, decarbonized, and digitized resilient energy system… [while also] enabling pioneering market and business models that provide clear societal, environmental, and economic benefits" (Hartnett et.al., 2018). Stavanger has the great potential for blockchain to be integrated into their Smart City project due to the positive actions they have already made as well as their "cooperative spirit" and their inhabitants desire for participation in response to environmental goals (City of Stavanger, 2016) Stavanger is also a city where renewable energies are of abundance, therefore, blockchain peer-to-peer sharing and energy markets may be of great interest to such a technologically and environmentally progressive community. On top of that, as of recently as mentioned, smart city of stavanger has already been introduced and attracted to blockchain technology through their CityZEN project.

Therefore, a very exciting potential option for blockchain integration into the Smart City projects is through the implementation of peer-to-peer energy trading utilizing microgrids. Today, the electricity we use is still generally produced by "one massive, centralized power plants that generate power sent long distances over transmission and distribution lines" with heavy intermediate involvement (Orcutt, 2017). These traditional forms of energy services are generally "incapable of sharing renewable energy simply and equitably, lack transparency around energy prices, [have a] long settlement period, [and] a lack of incentive to install new [green energy] developments" (Power Ledger, 2019).

However, Gupta, COO of The Solution Groups, suggests that it can now be possible for the utilization of smaller power generators to connect to blockchain-assisted microgrids that individuals on even a local or community level can partake in and buy or sell surplus renewable energies (2018). This opportunity establishes a more resilient power grid while preserving energy trade value (Gupta, 2018). This is exceptionally valuable for citizen value added experience wherein they can contribute to the energy market more directly and are incentivised to support and engage with smart technologies made available to them.

In such an energy grid, “each distributed energy resource would have a digital identity linked to its corresponding information, such as capacity and consumer preference” therefore, these identities actions “can be transparently tracked on the blockchain, and revenues can be divided and distributed automatically via smart contracts” (Hartnett et.al., 2018). This system of energy market provides the energy exchange platform where individuals are able to make their own decisions regarding where their energy is coming from, what type of energy they are receiving and ultimately receive renewable energies for a more realistic cost compared to purchasing from the main grid.

This technology paired alongside the Smart City project of Stavanger would allow individuals of the community to form smaller networks for peer-to-peer energy exchanges, encouraging community participation. For example, through the creation of a Smart City neighborhood, all houses in the neighborhood could be linked to their own micro-grid, each one contributing in some way as either a consumer or prosumer, of some sort of renewable energy. This allows for the individuals in a given area who are able to produce renewable energies themselves to be able to interact with their neighbors through the blockchain system and sell their extra energy production for a cheaper price than commercial energy.

Integrating blockchain peer-to-peer energy trading grids gives a lot of power and value back to the citizens by letting them participate in the energy market and make decisions for themselves and their energy consumption needs and preferences. Decentralization is a goal both on an international level as well as regional levels in so many ways. Countries, as well as individuals, do not want to be fully reliant and dependent on a resource that is so valuable and vulnerable to change. Therefore, decentralizing the production and trade of energy within smaller networks and grids, making third-party actors ultimately obsolete, benefits not only the individuals taking part in peer-to-peer energy trading, but also facilitating a more flexible platform for communities to further commit themselves to the utilization of more sustainable resources (Nehai & Guérard, 2017). When such an opportunity is accessible to a community, the incentive of personal production locally also increases, leading ultimately to the reduction of greenhouse gas emissions (Gupta, 2018).

3. Theoretical Framework

3.1 Diffusion of Innovations (DOI)

One of the two theories that I aim to utilize through this research as a framework for perspective and analysis is E.M Rogers's Diffusion of Innovations theory (DOI). This theory encompasses the idea that "when new innovations are presented to the public, the public will experience some level of uncertainty when deciding whether or not to adopt the innovation…[and will then] engage in information seeking behaviors to assess a variety of factors necessary in deciding whether to adopt the innovation" (Silk, Hurley, Pace, Maloney & Lapinski, 2014). This framework will assist well in this research study due to the actuality that blockchain technology and peer-to-peer energy trading is a rather new concept to the general public and therefore, there is likely uncertainty and discomfort surrounding the innovation. DOI theory comprises five adoption categories: relative advantage, compatibility, complexity, trialability, and observability, each of which aid in the decision-making process of such involved stakeholders (Silk, et al. 2014). By using this framework as a tool, it will be easier to discover which aspects of the adoption process needs to be addressed in order for the blockchain technology to be accepted and utilized by the public in Stavanger.

The relative advantage category of the DOI theory is "the extent the innovation is perceived to be better than other related options" such as economically in this case, comparing blockchain technology prices and profitability against traditional energy distributors (Silk, et al. 2014). Another aspect of relative advantage is the effectiveness of the new technology and whether the transition is going to benefit the user in some great way.

The second category of DOI is compatibility. This category refers to how much a new technology is reflective and compatible with the beliefs and values of the new potential user (Silk, et al. 2014). For example, if some social actors in the community do not believe that blockchain technology is of value or capable of having great environmental implications in terms of mitigating climate change, they will be less likely to adopt the innovation.

Complexity is another adoption category that refers to the difficulty of the new technology and how easy it is to grasp and understand (Silk, et al. 2014). This may be one area where blockchain technology adoption will experience difficulties due to the complexity and advanced technology that is used in blockchain. If a technology is difficult to use and comprehend, Silk et al. suggests that the likelihood of compliance will decrease (2014). Peer-to-peer energy trading will need to prove to be easily comprehensible in order for the general community residence of Stavanger to want to accept and utilize it.

Trialability is another aspect of the DOI theory. The DOI theory suggests that " innovations are more likely to be adopted if potential adopters have the ability to test the innovation...before full-blown adoption [as it] reduces uncertainty surrounding the innovation, increasing the likelihood that individuals will adopt the innovation" (Silk et al., 2014). Given that blockchain technology is implemented into a potential Smart City project in Stavanger, the feasibility of allowing trial of the technology seems rather do-able, then individuals can become more comfortable with the technology and then the transition.

The last adoption category in DOI theory is observability. This category focuses on the advantage that individuals being able to see the new technology being used before they are to take it on themselves has on adoption. Silk et al, suggests that this will aid in the uncertainty that the community may have towards the technology, evaluate in real time the effectiveness and in turn, increase the probability of acceptance (2014).

Through utilization of this framework, I will attempt to identify and assess the feasibility of implementing a transactive P2P energy system facilitated by blockchain technology into the Smart City of Stavanger.

3.2. Multi-level Perspective Theory

Another theory that is useful to this study is the Multi-level Perspective theory (MLP).

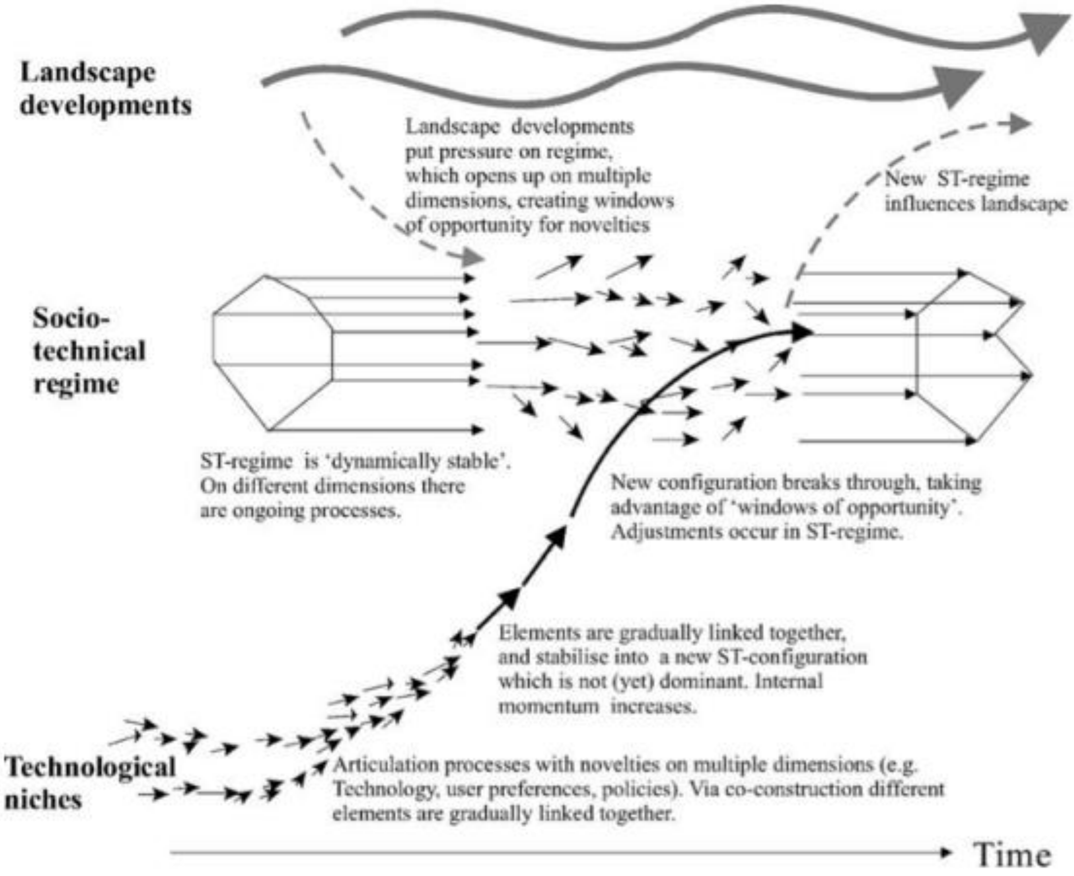

Figure 5. *Illustration of system change from a Multi-level Perspective (Hildingsson, 2014).*

The MLP is a socio-technical system which highlights the interaction between three levels being the regimes, niches and the landscape, and describes transitions as an outcome of regime shifts which do not occur easily due to the existing regimes being "characterised by lock-in and path dependence and oriented towards incremental innovation along predictable trajectories" (Geels, 2010). The technological regime is "the 'deep structure' that accounts for the stability of an existing socio-technical system" while the landscape is referred to as the level "…which influences niche and regime dynamics" (Geels, 2011). Frank Geels explains that it is the niches that are responsible for establishing new innovations that then challenge the existing regime in hopes for overpowering it and having the opportunity to transition away from the regime to the new niche technology (2010). Through the MLP, it is claimed that the niche technology will be more successful if the landscape aids in also applying pressure to the regime (Geels, 2010).

Through this theoretical lens, it will greatly aid in the understanding and analysis of the potential transition from the ‘regime’: the traditional form of energy distribution in Stavanger, to utilizing the ‘niche’ technology: blockchain peer-to-peer local energy markets, if at all achievable. In addition, the MLP will aid in answering proposed research questions regarding the potential hurdles, and legal implications of blockchain technology, microgrids and a P2P system of energy trading.

4. Methodology

4.1 Research Questions

This research paper aims to assess the feasibility of adoption and integration of blockchain technology into Smart Cities, with particular emphasis on Stavanger, Norway, and how it would impact the transition to renewable energies through the establishment of a transactive peer-to-peer microgrid. It will also explore the potential difficulties on both a legal, economic and social level in regard to the interdependencies, current market system as well as adaptability and adoptability of a new technology. If Stavanger is able to implement their own blockchain P2P energy trading network and microgrids into their Smart City project and communities, this research may open the doors to many other Smart City projects on a international level, enhancing the use of renewable energy consumption and production, thus leading to reduced $CO2$ emissions.

Research Questions:

Research Question 1: What factors may affect the adoption process or hinder the acceptance of such new and complex technologies?

Research Question 2: What are the potential barriers to establishing and operating a P2P local energy market in Stavanger?

4.2. Method

This thesis will be predominantly a qualitative method of study. According to Campbell, when a researcher chooses the qualitative method they take on more of an exploratory role through the collection of open-ended, emerging data that is used to develop themes (2014). Characteristics of this method may include partaking in a "natural setting, using multiple methods that are interactive and humanistic, emerging data rather than prefigured data, and being fundamentally interpretive" (Campbell, 2014). This holistic approach incorporates describing, explaining and interpreting collected data in order to establish connections (Williams, 2007).

This research method is the best choice for this study due to the ability I will have to assemble an overall picture and view of the feasibility of implementing blockchain technology into the Smart City of Stavanger. Through the combination of case studies and semi-structured interviews I will be able to make informed conclusions based on discovered patterns and processes as well as assess various industry desires and potential hesitations to the technology implementation. This study will include qualitative data that is both generated as well as collected.

4.3 Research Strategy

In order to determine the potential and impact of integrating blockchain technology and a microgrid network into the Stavanger Smart City, I have taken on an abductive research strategy. According to Norman Blaikie and Jan Priest, the purpose of the abductive strategy is "to understand social life in terms of social actors' meanings and motives" (2019). Beng Kok Ong stresses that the abductive research strategy highlights the importance of social actors' interpretations, motives and intentions which guide their actions and behaviors throughout their daily lives, thereby allowing the researcher to analyze and "generate scientific accounts from them" (2012).

This approach will aid my research in terms of remaining holistic as well as being able to "interpret and re-contextualize individual phenomena within a conceptual framework or set of ideas…[thereby] understanding something in a new way" (Danermark et al., 2002). Through the utilization of the abductive strategy, I will better be able to make sense of the research and the issue at hand given the placement of interpretation into a theoretical framework. Using a theoretical framework to conceptualize the permissibility of blockchain technology will give the research more insight, offer new ideas and guide the explanation of the phenomena at hand, therefore developing a better intellection of it (Dey, 2004). Through the application of the abductive research strategy, I intend to utilize the Diffusions of Innovation theory as well as the Multi-Level Perspective theory in order to widen the context of the research and gain new insight about the existing issue through examining it from a new perspective (Kovacs & Spens, 2005).

4.4 Data Collection

The data collection for this study is done through literature analysis of two international cases, the Brooklyn Microgrid in New York, and the Quartierstrom project in Switzerland as well as three interviews with prominent members of Stavanger Kommune Smart City team, the Head of the Department of R&D and Innovation at Lyse, and the CEO of blockchain based start-up bitYoga.

For this research, the type of interview that was chosen was semi-structured. Semi-structured interviews are "conducted conversationally with one respondent at a time…[and] employs a blend of closed- and open-ended questions, often accompanied by follow-up *why* or *how* questions" (Adams, 2015). It was important that the interview allowed for *why* or *how* questions considering the immaturity of the concept and the interviewers lack of knowledge in their particular fields. It allowed for a more light and engaging environment without allowing for too many distractions away from the intended interview questions. The interviews lasted approximately one hour for the smart city and utility company participants and thirty minutes for the blockchain start-up company participant. According to Adams, one hour is about the maximum length of time that should be taken when conducting semi-structured interviews in order to avoid fatigue from both the participant and the interviewer (2015).

I chose case studies as the other method of my data collection due to their ability to be used to make wider generalizations, and "investigate a contemporary phenomenon within its real-life context, especially when boundaries between phenomena and context are not clearly evident" (Blaikie and Priest, 2019). Case studies were therefore important to the study considering there are no projects in Norway that enable a P2P energy trading system. Accordingly, it was essential to examine international cases in order to congregate an understanding of what such a technological concept would look like in the real world.

Additionally, to see if any generalizations could be applied or a level of replication could be administered in Norway.

4.4.1 Selecting the Cases

As mentioned, one of the styles of data collection I have chosen to deploy for this research is an analysis of two cases. The reason I chose to analyse two cases, rather than just one, was because energy law, regulations, access to renewable energy, consumer behavior, amongst various other aspects of energy, are very different all over the world. With that being said, by only looking at one case, it wouldn't be equitable to make generalizations. Rather, by analysing two cases, I will have a greater ability to recognize similarities, differences and identify patterns through the process of implementing blockchain based local energy markets (Blaikie and Priest, 2019).

Accordingly, the cases I have chosen to analyze are the *Brooklyn Microgrid* demonstration project in the United States and *Quartierstrom*, a pilot project in Walenstadt, Switzerland. The reason I have chosen these distinct cases is because they are both directly associated with blockchain technology as the foundational platform for citizen involvement in energy trading from their own residential homes using microgrids. In addition, both projects have been conducted in developed countries of the world (Switzerland and the United States), ergo, it can be delicately assumed that the current applicability and regulatory framework surrounding blockchain and microgrids would be similar to that of Norway. These two projects are two out of the few of their kind. Blockchain technology, peer-to-peer energy trading and microgrids are all still quite immature, especially when combined together. Many specialists have begun research on such concepts, but have not actually undertaken testing and implementation. Therefore, these two case studies are of significant value for future peer-to-peer projects and especially for this research project, aiding in understanding as well as the 'transferability' and 'fittingness' of such a concept into the Smart City of Stavanger (Blaikie and Priest, 2019).

4.4.2 Selecting the Interviewees

In addition to the two case studies, three semi-structured interviews were also conducted with relevant actors in Stavanger, Norway. Interviews were essential for this research project considering there is very little known activity or information available regarding blockchain technology, as well as P2P projects relating to energy trading in Stavanger. Therefore, generating my own primary data was of importance.

It was of importance for this study that I gained access to those with a holistic approach to the implementation of blockchain technology as well as microgrids into Stavanger Smart City, rather than someone of very technical know-how, as that is not the main focus of this first research study. Initially, I had only planned on interviewing one person, ideally someone from the municipality with great knowledge and insight regarding Stavanger Smart City. However, once I met with them, a snowball effect took shape and others were suggested to be met with in addition. The first person I met with, by suggestion of my supervisor, Thomas Laudal, was Gunnar Crawford, the Head of Stavanger Smart City. During my interview with him, he suggested that I speak with someone from the main utility company in Stavanger, Lyse. Thus, I made the connection with Dagfinn Wåge who is the Head of the Department of R&D and Innovation at Lyse. Snowballing again, during my interview with Dagfinn Wåge, he prescribed a meeting with the CEO of a start-up company that he is working with at the moment called bitYoga. Therefore, that is how I met and came into contact with Antorweep Chakravorty.

Gunnar Crawford, being the Head of Stavanger Smart City was chosen to give insight into the values, priorities, experiences, and internal working and decision making of the municipality and local Smart City projects. Dagfinn Wåge was of great value coming from the utility company side of things considering if P2P energy trading over a blockchain platform were to occur in Stavanger, Lyse would irrefutably be affected in many ways as they maintain the monopoly in Rogaland of power distribution. Finally, Antorweep Chakravorty, CEO of bitYoga, was great to be put into contact with as his start-up company is a blockchain platform designed to enhance data privacy (bitYoga, 2020). He is also working with the EU Horizon 2020 project called ARTICONF, which is a “smart social media ecosystem in a blockchain federated environment” that also works with smart energy (ARTICONF, n.d.).

Having conducted more interviews than I had initially planned was very beneficial as my data was enriched and more answers were given to emerging questions from the interviews prior.

5. Validity and Reliability

When writing a qualitative research paper, the concepts of validity and reliability become of great importance and are critical to take into consideration. These terms are two key aspects of all research as they aid in the measurement and evaluation of the study's quality (Cypress, 2017). In the realm of social science, validity can be broadly described as "the state of being well grounded or justifiable, relevant, meaningful, logical, confirming to accepted principles or the quality of being sound, just, and well founded," or more simply, that it is accurate and trustworthy (Cypress, 2017). Therefore, to ensure validity throughout this study, I first made sure that I chose interview participants who were relevant as well as prominent and knowledgeable actors within their field. This was of great importance in order to ensure that the information that I would receive could be trusted and meaningful. This was also relevant in regards to the case studies and making sure they were concrete and valid representations of a successful international P2P energy market. I also ensured that the interview questions were of relevance to the study and that there was enough structure as to keep the focus of the interviewees. It was also fundamental that I remained unbiased throughout the interview process so as to not sway the respondents' responses in any way.

In contrast, reliability refers to the level of "replicability, repeatability, and stability of results or observation" (Cypress, 2017). In a qualitative study, especially involving interviews, it can be difficult to ensure high levels of reliability, therefore, "a margin of variability for results is tolerated in qualitative research…" (Leung, 2015). Considering the concept of blockchain technology and P2P energy trading platforms are still relatively immature, it may be wrong to say that next time an interview is conducted, the same results will be achieved. Technology is continuously advancing and the mindsets of individuals regarding what is possible and what is not is changing as well. However, the level of reliability in regards to the case studies remained reliable as they were compared amongst others of their kind for data accuracy. However, during the interview process, to ensure the highest reliability, I ensured that all the questions were delivered the same to each respondent and that I set the stage for the purpose of the study and what the concept entailed in the same way.

6. Ethical Considerations

With any research study, there are many ethical principles that need to be considered. Blaikie and Priest highlight some of the core principles to be respecting the autonomy and dignity of those involved in the research study, maintaining scientific value, respecting the social responsibility as a researcher as well as ensuring that benefits are maximized, minimizing the potential harm on anyone involved (2019). Considering this study utilized interview respondents, where I would be gathering personal information, I first registered the project through the Norsk Senter for Forskningsdata or the Norwegian Centre for Research Data (NSD) to ensure that my interviews would be conducted in an ethical and legal manner and executed properly. Once the application was confirmed, I was able to begin setting up meetings for interviews.

In order to conduct the semi-structured interview, I first reached out through e-mail wherein I explained the purpose of my study, and what the research is about. I also expressed my desire to speak with them and the great value that I believed they would add to this thesis. It was of importance that I made sure the respondents knew that participation was voluntary, they were not being coerced into participating, and that they could at any time decide to cease participation (Qu & Dumay, 2011).

If the individuals responded to my email and agreed to set up a meeting time with me, I would create the consent form consisting of the suggestions given by the NSD for that interview. In terms of this particular project, it was important to keep participants in-the-know in regards to all aspects of the research and where it is going in order to avoid deception at all costs (Connelly, 2014). In order to ensure that the participants were aware and comfortable, I first distributed the statement of purpose and consent form before the interview was conducted. On the consent form it asked whether or not they would be comfortable with me using their names in the final thesis. Gunnar Crawford and Dagfinn Wåge consented in writing on the form, while Antorweep Chakravorty agreed orally due to his current position as CEO.

7. International Case Studies

Although the integration of blockchain technology directly into Smart City projects has not yet made its grand debut, there are a few companies that have made blockchain peer-to-peer energy trading a reality through various pilot applications. In this section I will identify and describe noteworthy examples of successful P2P energy trading platforms utilizing blockchain technology and microgrids, to add to technology and application comprehension as well as illuminate possible roadmaps of what may be able to occur in Stvanger, Norway.

7.1 Brooklyn Microgrid Case Study

7.1.1 Project Description

One of the most familiar examples of a P2P energy trading platform is the Brooklyn Microgrid in New York, USA, run by LO3 Energy. The Brooklyn Microgrid project (BMG) was the very first of its kind, to successfully facilitate a P2P energy transaction between city residents and small business owners utilizing blockchain technology (Mengelkamp, Garttner, Rock, Kessler, Orsini and Weinhardt, 2018). In order to operate such a system, a microgrid encompassing participants across three distribution networks was put in place which allows users to disconnect from the main grid and manage their energy supply independently within the community as well as trade clean local energy with their neighbors (Mengelkamp et.al., 2018).

The prosumer homes in this project are equipped with rooftop solar PV panels, responsible for generating renewable electricity on a local level and therefore allowing for a local energy market (Mengelkamp et.al., 2018). In addition, the consumer households are equipped with the necessary technical infrastructure to also engage with the local market such as transactive smart meters and transactive grid blockchain architecture (Mengelkamp et.al., 2018).

According to Mengelkamp et.al., the BMG project embodies two parts: one virtual layer, and one physical layer (2018). The virtual component refers to a community energy market platform which provides the technical architecture utilizing a private blockchain to enhance the security of the power supply as well as the platform which facilitates the community member control and interaction with their electricity (Mengelkamp et.al., 2018). The physical layer is the microgrid itself which is built into the existing traditional grid for the sake of being able to disengage and function in island-mode given an emergency to avoid blackouts (Mengelkamp et.al., 2018). All of the electricity transactions and flow occurs on the utility grid, however, the data collected from the residential smart meters flows through the virtual platform and then to the individual blockchain accounts of the participants (Mengelkamp et.al., 2018).

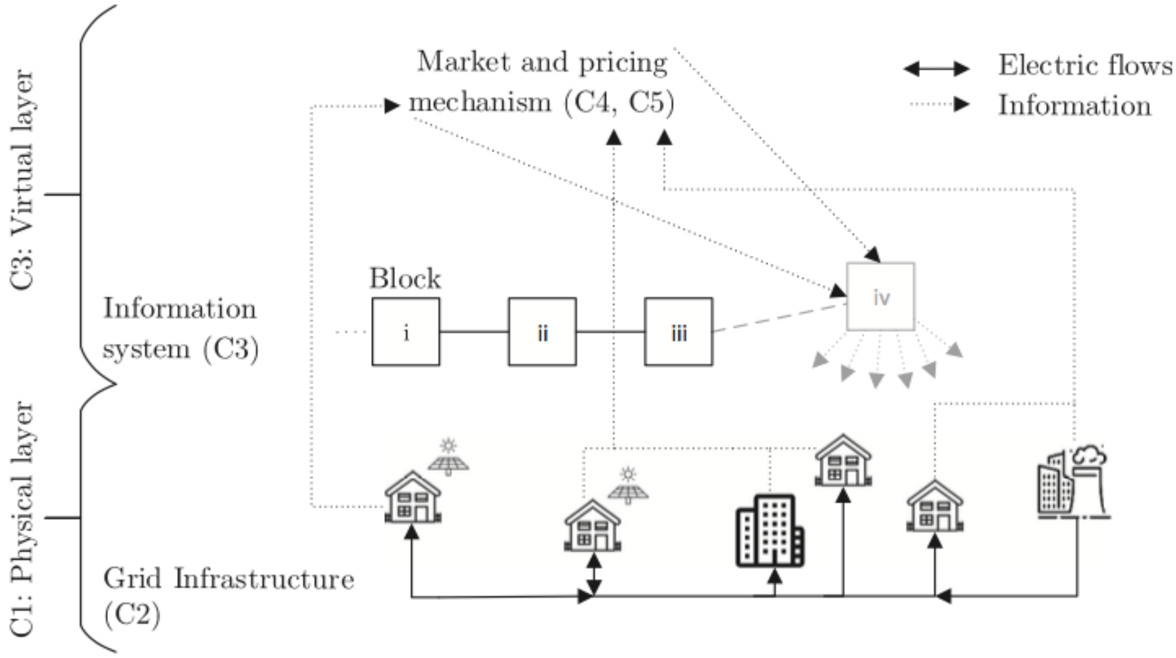

Figure 6. Topology of the Brooklyn Microgrid (Mengelkamp et.al., 2018).

The residents participating in this project access the local energy market through logging into the Brooklyn Microgrid smart phone application, where they can then, depending on whether they are consumers or prosumers, set their daily limits of how much they would like to either buy or sell their electricity for (Brooklyn Microgrid, 2019). A smart contract is utilized to allow trades to occur automatically based on the consumer and prosumers preferences as well as enforce predetermined payment rules (Mengelkamp et.al., 2018). The smart meter installations record the amount of electricity produced and consumed by each residential home or business and it is shared over the blockchain, allowing for buy and ask orders to be generated according to such data (Mengelkamp et.al., 2018). The transactions are then matched and carried out through an auction system every 15 minutes (Mengelkamp et.al., 2018). Once completed and the payments are received, a new block gets added to the blockchain (Mengelkamp et.al., 2018). If the prosumer participants do not need to consume more of their own generated electricity they have the option to either sell it in their local marketplace or continue to partake in net metering with the utility company (Brooklyn Microgrid, 2019). According to Zahid et.al., (2020), net metering is a mechanism that allows prosumers to transfer their extra generated electricity to the utility grid utilizing a bidirectional billing system. When the prosumer later wants to reobtain their energy, “the extra exported electrical energy can again be drawn on the same rates as it was transferred to the utility grid” (Zahid et.al., 2020). In this way the traditional utility grid is treated as a sort of battery for the prosumers extra energy (Zahid et.al., 2020).

7.1.2 Objective

The experimental project first began on a small scale in April 2016, with the ambitious outlook of “...reimagin[ing] the traditional energy grid model by incorporating the concept of a communal energy network in which residential and commercial New Yorkers can buy and sell locally-generated, renewable energy” (Brooklyn Microgrid, 2019). This particular microgrid was established to address the increasingly severe weather activity, which has affected the city and their access to power as a result of the outdated and unstable electrical grids which have been prone to grid failures, offered in Brooklyn (Mengelkamp et.al, 2018). This particular region of Brooklyn (Borough Hall), was also known to experience a lot of grid congestion (Mengelkamp et.al., 2018).

This project not only increased the amount of locally produced renewable energy for power supply security, but also empowered the community to take on responsibility and gain relevant knowledge regarding their own power supply and consumption (Mengelkamp et.al., 2018). The participants of the BMG project were extremely keen on partaking and demonstrating that the project is backed with intense desire and support of the community, eager to pursue legislation restructuring.

7.1.3 Regulatory Issues

Across legislations on a global field, peer-to-peer energy trading, or more specifically, the trading of energy for money, is still not permitted within current legislation (THEMA, 2019). Therefore, after the test project of the BMG project on a small scale, leaders of the project created a petition to push the project even further and campaign a request for a ‘regulatory sandbox’ project which will allow for the BMG to operate as a commercial entity and perform energy transactions (Maloney, 2019). Van der Wall, Das and van der Schoor claim that the option of a regulatory sandbox was created by regulators to assist in the energy transition by creating a “participatory experimentation environment for exploring revision of energy law in several countries…[and] allow for a two-way regulatory dialogue between an experimenter and an approachable regulator to innovate regulation and enable new socio-technical arrangements" (2020). This means that legislation can be loosened or amended temporarily to allow for the testing of new innovations before actually implementing new laws while under the supervision of regulators.

With that being said, the continuation of the BMG project on a larger scale was accepted in April 2019, and enacted as the "New York Microgrids Act" (The New York State Senate, 2019). According to the New York state senate governmental webpage, Senate Bill S5114 "enacts the "New York microgrids act" to establish the microgrids of New York grant program within the New York state energy research and development authority; such program shall award monies to certain areas of the state for the purposes of reducing utility rates, reducing utility demand and encouraging use of renewable energy resources" (The New York State Senate, 2019). Considering microgrid and blockchain projects are still quite immature and have yet to find their legal and social grounds in societies, regulation is still very difficult to implement. Research and new ways of working with these technologies in the energy sector are still developing and changing, therefore making it unattractive to change current legislation and regulations permanently.

7.2 Quartierstrom Case Study

7.2.1 Project Description

Another international case that has successfully implemented a P2P energy trading market through the collaboration of blockchain technology and microgrid infrastructure is the Quartierstrom project in Walenstadt, Switzerland. This particular project began field implementation in January of 2019 and finished in January 2020 (Ableitner et.al., 2020). *Quartierstrom*, directly translated from the german language meaning 'district power', or 'district electricity', is backed by the pilot, demonstration and flagships program of the Swiss Federal Office of Energy (Ableitner, Meeuw, Schopfer, Tiefenbeck, Wortmann, Wörner, 2020). This particular pilot project is operated by Wasser-und Elektrizitätswerke Walenstadt and is comprised of 27 solar energy prosumers and 10 exclusively consumer participants (Brenzikofer, Meuw, Schopfer, Wörner, Dürr, 2019). In addition, 8 of the 27 solar prosumers are already equipped with their own battery storage systems installed, while another larger battery was implemented into an apartment building within the Quartierstrom project network (Ableitner et.al., 2020). Collectively, the community can capacitate 280 kWp of solar PV energy and has a total storage capacity (through lithium ion batteries) of 80 kWh (Ableitner et.al., 2020).

Many of the technical details of this project are similar to that of the Brooklyn Microgrid project, as the North American project was one of the first of it's kind to present a successful P2P energy transaction utilizing blockchain technology and microgrids. With that being said, Quartierstrom project also utilizes a permissioned (private) blockchain designed to guarantee transparency, integrity, information security and confidentiality throughout the entire P2P energy trading process (Brenzikofer and Melchior, 2019). This is further enforced through the use of smart contracts to ensure that rules are followed and transactions are carried out in the correct manner.

This residential project operates through the cooperation of three principal elements. These three elements are the blockchain infrastructure, a market application that also runs on the blockchain, as well as the user interface (Ableitner et.al., 2020). The blockchain infrastructure encompases and promises the trademark features of blockchain explained previously, such as enhanced security and decentralization, while the market aspect running on the blockchain refers to the projects double auction mechanism that aids in determining the price of the locally produced solar energy (Ableitner et.al., 2020). Thirdly, the user interface is a web application that allows control to be handed over to the residents of the individual homes and where they can access the neighborhoods consumption and generation statistics as well as set prices for their desired energy needs.

In functionality, the prosumers and consumers first log into the user friendly web application on one of their devices where they can stipulate the price they are comfortable and willing to buy or sell locally generated solar electricity for without the need for an intermediary setting the exact price and then expecting consumers to just take it (Brenzikofer, Meuw, Schopfer, Worner, Durr, 2019). As mentioned, this project utilizes a double auction system through smart contract with discriminatory pricing (the mean of buyer and sellers bid/offer price) and orders are transmitted through smart meters "containing the price limit determined by the individual household and the electricity demand or supply measured by the meter" (Brenzikofer & Melchior, 2019). These orders are collected and categorized by price in 15 minute intervals favoring first the lower sell bids and higher buy bids, then transactions are automatically calculated and stored on the blockchain in real time (Brenzikofer & Melchior, 2019 & Ableitner et.al., 2020).

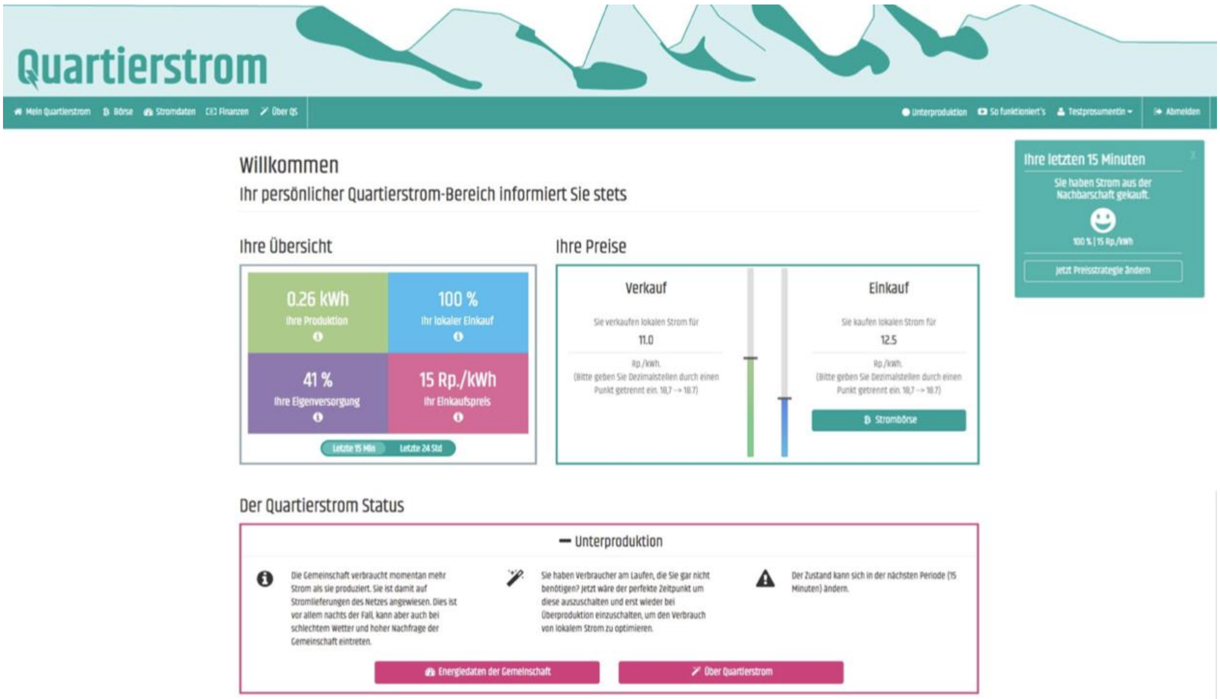

Figure 7. *The prototypical user interface home page of the Quartierstrom project (Ableitner et.al., 2020)*

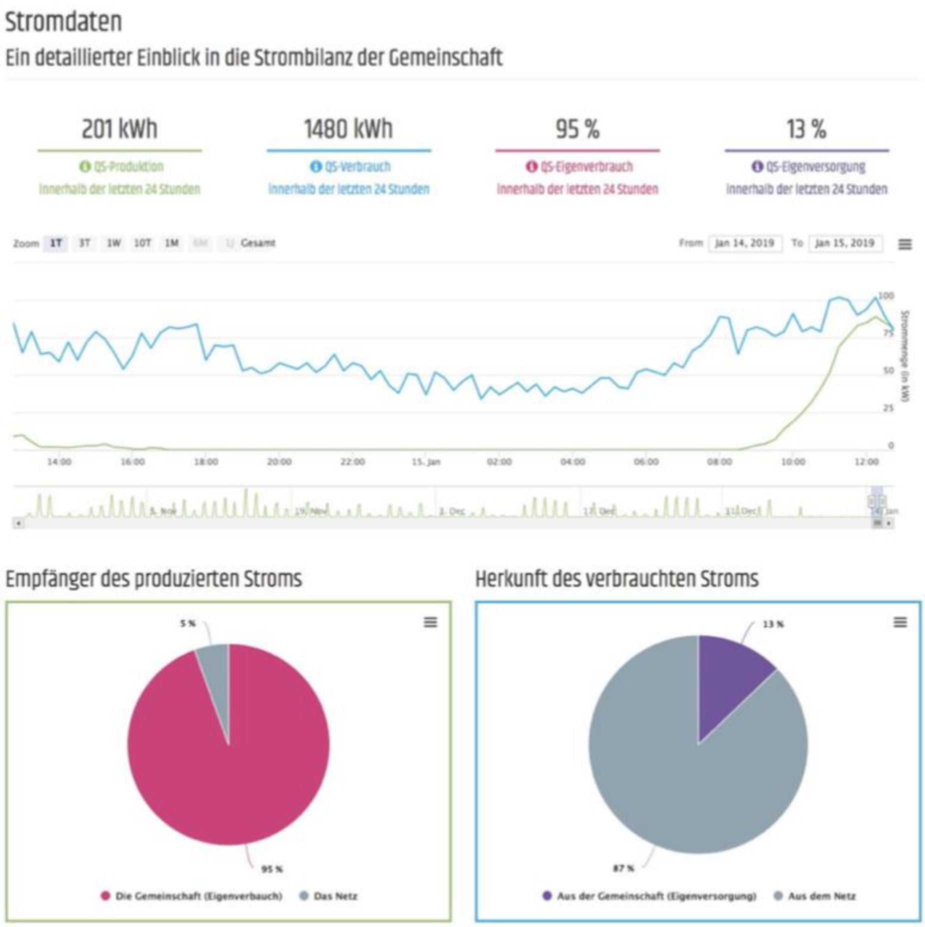

Figure 8. *The "My Energy Data" page of the Quartierstrom user interface* (*Ableitner et.al., 2020)*

The two figures above are screenshots from the user web application as seen by the residents of the Quartierstrom project. Figure 6 is the 'landing page' of the user application that illustrates key insights of the household's energy such as how much they have individually produced, how self-efficient they are, as well as the place where they can slide to adjust their purchase and sell prices for the local marketplace (Ableitner et.al., 2020). Figure 7 above, is the "My Energy Data" page of the interface, noted as the most popular and most visited page by participants, where they are able to see a more detailed picture of production and consumption statistics of the whole Quartierstrom community (Ableitner et.al., 2020).

What makes this project stand apart from the Brooklyn Microgrid project however, is the involvement of the traditional utility company. Switzerland is a country that has one of the “lowest carbon intensit[ies] among all IEA countries, owing largely to the carbon free electricity sector that is dominated by nuclear and hydro generation” therefore, there is really no need in a case as such to eliminate the utility company entirely (IEA, 2018). That being said, Quartierstrom still maintains the belief that it is important to keep production and consumption of distributed renewable energies as local as possible (Ableitner et.al., 2020).

The way that the traditional utility company remains involved is through their participation in the established local market as a “collector of grid usage tariffs and as a fall-back prosumer for any mismatch between market and physical flow of power” (Brenzikofer, Meuw, Schopfer, Worner, Durr, 2019). According to Brenzikofer et.al., with a decentralized system as such, “a dynamic grid usage tariff is implemented to align pure energy market incentives with grid stability interests” (2019). In other words, given the possibility that demand or supply of energy cannot be met in the local community, the traditional energy utility company acts as a backup to balance out and fulfill the needs of the community at fixed tariffs (Ableitner et.al., 2020).

Come the end of the pilot project that lasted the full calendar year of 2019, a final report was released providing detailed insight on discoveries, and measurement of successes and non-fulfillment of the Quartierstrom project. According to the leaders of the Swiss project, their implementation of a P2P energy trading platform utilizing blockchain technology among residents in Walenstadt was successful (Ableitner et.al., 2020). Overall, through the development and implementation of this P2P local energy market, self-sufficiency and self-consumption of the community almost doubled from 21% to 39% and 34% to 62% respectively (Ableitner et.al., 2020). The residential participants responded and took to the complex technology mechanisms and entire experience more positively than expected and were very interactive on a regular basis with the user interface (Ableitner et.al., 2020). However, there were comments in favor of more automation (Ableitner et.al., 2020). The technological feasibility of the system itself proved to be stable, reliable and achieved proof-of-concept, nevertheless, the pilot still revealed challenges regarding scalability and privacy concerns such as the display of individual home consumption statistics (Ableitner et.al., 2020).

7.2.2 Objective

The ultimate goal of Quartierstrom was to examine "...a transactional energy system that manages the exchange and remuneration of electricity between consumers, prosumers and the local grid provider in the absence of intermediaries" (Brenzikofer, Meuw, Schopfer, Worner, Durr, 2019). More specifically, the Quartierstrom official report, *Community Energy Network with Prosumer Focus*, specified and categorized six formal objectives: technical feasibility, platform and market design, user behavior, regulatory environment, business model, and communication (Ableitner et.al., 2020).

The goal regarding technical feasibility was set in order to thoroughly assess and gauge how well blockchain technology could actually facilitate such an energy ecosystem without the need for intermediaries (Ableitner et.al., 2020). In addition, it was important to the success of the project to fully understand the complexities and requirements that the actual hardware of the technology has in order to evaluate the overall impact on society.

Platform and market design was an objective that was necessary in order to find the best solutions to not only distribute the energy through and figure out how to accurately price the energy in a local market through smart contract, but also in producing incentives to increase local balancing within the community (Ableitner et.al., 2020).

In order to have a successful P2P energy trading network, it is necessary to have participants on board and fully knowledgeable about the technology and what it is that they are doing. Therefore, an objective regarding user behavior was prioritized in order to test and find designs for the most user-friendly, comprehensible interface for participants to fully accept and adopt the technology (Ableitner et.al., 2020). It was important to create a platform where the residents could easily navigate, access data, and be an interested, active member of the project.

The objective of regulatory framework was principal in order to understand and comply with the current regulatory environment and developments in Switzerland as well as internationally (Ableitner et.al., 2020) This objective is important in order to proceed with current and future projects regarding P2P energy trading on a local level but also having knowledge on where to proceed next in terms of regulation amendments and alterations.

The Quartierstrom project also wanted to evaluate various business models " in light of technical and regulatory developments…[in order to] analys[e]...the current situation as well as a forward-looking perspective of future opportunities that might arise if the regulatory environment changes was proposed" (Ableitner et.al., 2020).

Lastly, communication. Communication was listed as an objective of the project in order to expose the project to more than just the academics. Quartierstrom therefore experimented with different media sources of exposure such as blogs, press, and newsletters to get their message and story out (Ableitner et.al., 2020).

In summation, this project predominantly aimed at presenting a roadmap of a technically feasible option and solution to increase the use and value of generating and purchasing locally produced renewable energy, in addition to presenting the notion that a local energy market running on blockchain is possible and sustainable without having to deem traditional utilities obsolete (Ableitner et.al., 2020).

7.2.3 Regulatory Issues

As previously mentioned, most countries around the world still do not allow for the trading of energy between neighbors (Sousa, Soares, Pinson, Moret, Baroche, and Sorin, 2019). This includes Switzerland. However, Switzerland legislation is currently more progressive than many other countries (Ableitner et.al., 2020). According to Ableitner et.al. (2020), peer-to-peer communities in Switzerland are currently only possible under the current legislation if they meet the following four conditions. First, "all plots are adjacent to each other or separated only by a road, railway line, or river, or the peer-to-peer community is located on an area network" (Ableitner et.al., 2020). In other words, it needs to be within a small area. Secondly, Ableitner et.al. (2020), stress that the community trading energy must use a separate grid network as such communities may not use the electrical power utility's distribution network. Third, "If several landowners are end-users at the place of production, they may join forces for their own self-consumption, provided that the total production capacity of the installation is at least 10 percent of the connected load at the measuring point of the self-consumption community" (Ableitner et.al., 2020). Fourth and final the integration of properties that are not adjacent is not possible (Ableitner et.al., 2020). In addition to the four conditions, there are also other rules and regulation that fall under Swiss laws and legislations. For instance, "contractual relationships must be established and structured differently depending on whether the trading-platform is owned by a third party" " (Ableitner et.al., 2020). Such third parties can be the network operator or another contracting partner, or the community itself.

Through the implementation of Quartierstrom, it was claimed that in order for any similar projects to achieve rapid adoption, success, scalability and real-life execution, the current regulatory framework is going to have to change to accommodate local energy markets to operate on public networks (Ableitner et.al., 2020). Therefore, "a fast setup of a sandbox policy framework, legislative progress, and regulatory certainty are vital for scalable and sustainable business models such as those proposed to emerge " (Ableitner et.al., 2020).

Accordingly, the leaders suggest that "the operation of a P2P market on a centralized server infrastructure by a grid operator or a utility provider seems like a viable option- in particular given the technical hurdles arising from the nascent status of blockchain technology and relevant technical know-how" (Ableitner et.al., 2020). On a small scale, the project was very achievable, however, in the future, when the project plans to expand, there will be many more technical, and regulatory barriers that will need to be overcome (Ableitner et.al., 2020).

8. Discussion and Analysis

The all-embracing purpose of this study was to assess the feasibility of implementing a blockchain based peer-to-peer energy trading platform-utilizing microgrids into the Smart City of Stavanger. My goal was not to create a road map as to *how* to develop or *how* to implement such a system, rather, after discovery that research and pilot projects have been taking place in other parts of the world, if this was something that Stavanger could benefit from and desire to bring into reality for their citizens. In this section, utilizing the chosen theoretical perspectives, I will interpret and analyse the results of the semi-structured interviews and draw applicable insights from the case studies in order to answer the research questions intended of this study.

Research Question 1: What factors may affect the adoption process or hinder the acceptance of such new and complex technologies?

One of the main concerns when implementing such a complex and relatively new technology is whether members of a society will respond positively and choose to adopt it into their lifestyles. When it comes to blockchain technology, most people have heard something about it, it may ring a bell in their mind, however the general knowledge on the topic is rather small. Blockchain technology is very advanced and the way it actually operates is only of concern or interest now to a small portion of the population. With that being said, under the theoretical lens of E.M Rogers's Diffusion of Innovations theory, the public is likely to experience various levels of uncertainty and evaluate different categories of adoption: relative advantage, compatibility, complexity, trialability, and observability (Silk et.al., 2014). However, when discussing the introduction of smart city innovation to Stavanger citizens, Gunnar Crawford shared his personal experience that the response has continuously been very positive, the residents were always really ready for it and eager to participate in the projects presented to them (Personal communication, July 29, 2020). Comparatively, he explained that the more prominent source of uncertainty regarding innovation adoption takes place internally, from the actors of the municipality. The interviewee highlighted that for such a municipality, it is quite strange because the team has conducted projects that encompass a lot of knowledge and are capable of a lot of smart things (smart technology), however, they are not really that open to new ideas. Therefore, the adoption process of blockchain P2P energy trading over microgrids will be analysed focusing on the internal actors from the Smart City of Stavanger as well as the utility company, Lyse.

With the DOI theory in mind, the adoption concept of relative advantage has shown to be one of the most prominent adoption categories reflecting the hesitant decision-making process of the prominent actors in Stavanger. One of the biggest reasons for this is that Norway already enjoys inexpensive electricity and renewable sources account for 98-99% of their total energy generation (Fosso, Molinas, Sand, Coldevin, 2014). For that reason, it can be argued that decentralization and phasing-out of the traditional utility company is unnecessary. According to Gunnar Crawford, Norway is very lucky in many aspects of life and they have very different 'triggers' for change in comparison with other countries. He suggests that in this country, it is very difficult to 'trigger' people solely in relation to the economy. The economy in Norway is quite strong, therefore, there needs to be more of an incentive than that. The respondent continued through comparison to Germany, suggesting that in a country like that, it can be about the economy, and it can be about avoiding nuclear or other types of energy. The respondent contrasted Germany to Norway in the following excerpt:

> The only reason why we could say that we would like to reduce our consumption is for future generations, it's for our EV's, and it's about the game of import-export...other than that, there is really no reason...everything is renewable...it's hydro. (G. Crawford, personal communication, July 29, 2020)

Therefore, the relative advantage is quite low at this time in regards to the innovation system presented in this study. To paraphrase what Crawford mentioned, it is difficult to really state to a country like Norway that it *needs* to change, when they really don't need to, but they do still *want* to change.

In terms of compatibility, referring to how much an innovation is reflective and in-line with the beliefs and values of the adopter, blockchain technology facilitating a P2P energy trading platform for citizens utilizing microgrids has an alignment. According to Dagfinn Wåge, head of the innovations department at Lyse, people in Norway like to own things. The following excerpt highlights the comparison:

> If you go to Sweden or Denmark people are renting their flat their whole life. They don't buy anything, and they are happy with that. In Norway they're not. They want to buy [their] flat, their house. You want to buy your car. You want to buy your cabin….and you just want to own it. So it's like "my precious". (Dagfinn Wåge, Personal communication, July 30, 2020).

There is something there for Norwegians in terms of wanting ownership and the prosumer lifestyle. According to a THEMA report commissioned by the NVE, there has been an increase in the past few years of "end-user awareness of environmental issue[s] and therefore greater value associated with offering environmentally friendly products and services" (2019).This can further be seen through the increased sale of solar PV and electric vehicles in the country, indicating that there is "a growing number of consumers that want to take an active part in their energy consumption and produce their own electric energy" (THEMA, 2019). Therefore, by implementing the technology system that this study presents, Norwegians would have increased control and ownership over their own power generators, their consumption and production, know where it's coming from, how much they are using, and how much they want to buy and sell it for.

Complexity is another category that needed to be taken into perspective for adoption of the new innovative blockchain P2P system. In terms of complexity, both Crawford and Wåge agree that those within the energy sector have accepted the technical side of blockchain in terms of what it does and that it works. However, what Wåge in particular still finds problematic in terms of complexity is the actual real world implementation and the relationship between the utility provider and local energy communities (D. Wåge, personal communication, July 29, 2020). Through another interview with the CEO of bitYoga, Antorweep Chakrovorty, the complexities around blockchain for the end-users was discussed. Chakravorty suggests that if we simply say to a normal user *"Can you use blockchain?"* They most likely will not know what that means. It's complex. Therefore, it is important to instill the core value of blockchain and instead utter, *"do you want a service which will provide you with quantifiable trust?... A system where you can know that the information you are provided is genuine?"* He illuminates that people are more inclined to choose a service that is trust based. Blockchain when combined with the user interface is very easy for everyday people to use and understand. Blockchain is simply the database that the users will be active on (A. Chakravorty, personal communication, August 4, 2020). This can be compared to something along the same lines as the Quartierstrom user interface shown previously in Figure 6 and 7.

In terms of trialability, the suggestion that innovations that are able to be tried out first are more likely to be adopted, there has been no opportunity for citizens of Stavanger yet (Silk et. al., 2014). According to a report commissioned by the Norwegian Water Resources and Energy Directorate, there are currently no "full-scale energy communit[ies] with inhabitant involvement and grid congestion management through either a community market or dynamic pricing signals (THEMA, 2019). Therefore, no citizens or actors in Norway have been able to test out or experience such a concept. In contrast, the case studies above were pilot and demonstration projects, with real citizens trying out the technology and community system, therefore, trialability was achieved. Through the Quartierstrom case study, it was highlighted that the trial projects were very successful, and participant responses were much more positive than expected (Ableitner et.al., 2020). By the end of the trial, there were no participants who wanted to back out of the project, rather just had recommendations on how to further allow it to make their lives easier through, for example, more automation (Ableitner et.al., 2020). Even though there are no current trialability options for the citizens of Stavanger, all the interview participants said that there was definitely movement in this sort of direction and discussions were being had. It is beginning to be considered and formulated, however currently it has not been able to get past a concept stage and become an actual business case.

The adoption category of observability is in a large way another main area of hesitation for stakeholders in Stavanger. As mentioned in the theory section, this category is regarding the comfort that potential adopters will feel if they are able to see the new technology being used before they implement it into their own lives (Silk et.al., 2014). Wåge highlights that this concept is still very immature considering only pilot projects have been done to prove that it can work. However, there have been no regulatory adjustments to actually implement it into citizens' everyday lives. At this point, on a global level, it is still uncovered by regulatory frameworks.

Antorweep Chakravorty accentuates that in regards to blockchain technology and a P2P network of energy traders, everyone is still waiting for someone else to do something, for the market to evolve, and big corporations are not making the move, even though the underlying infrastructure is already in place (Personal communication, August 4, 2020). Especially in Norway, where the incentive is already quite low in the first place, it is unlikely that they would be the first ones to tackle something like this without seeing it happen on a full-scale first. Chakravorty alluded that *"when the market wants to do something then things will change and happen...right now everyone is waiting to see what will happen before they adopt it into their ecosystem"* (Personal communication, August 4, 2020).

To summarize what was gathered from the respondents regarding the adoption process of blockchain technology and a P2P energy trading platform, Norwegain citizens are ready to take on such a concept. Through the Smart City projects, they have been introduced to new technologies and have shown great response and eagerness. Where the real hesitation and uncertainty in regards to adoption is coming from is internally. Internally, Municipal, industrial and legal level actors are struggling with a very traditional mindset and know that what they are doing is working, therefore, why change? (G. Crawford, Personal communication, July 29, 2020).

Research Question 2: What are the potential barriers to establishing and operating a P2P local energy market in Stavanger?

Through the results of the semi-structured interviews as well as the case studies, the largest barriers to establishing and operating a P2P local energy market is due to current regulation and industry. According to the interview respondents, there are reasons that energy regulations are so strict, and that is because it is a very real, very dangerous, and very essential part of our lives. Therefore, for the purpose of this research, it was important to discover what in particular, in regards to industry and regulation, is holding Norway back from bringing the concept discussions away from the meeting tables and into the city of Stavanger. These main barriers will be narrowed down to safety and balancing, asset and ownership control, licencing, grid tariffs and investments and lack of a quality business model.

One of the most prominent barriers discussed by interviewees for the implementation of a P2P based trading platform utilizing microgrids at the moment is safety and balancing. As mentioned previously by respondents, electricity can be very dangerous and requires knowledge and know-how in regards to how to safely operate it. Crawford states that in Norway, it is only the utility companies that are able to do maintenance on such high voltage equipment. Other electricians are not qualified or even legally allowed to work on them. They are really only able to work on voltages up to around 240 volts, no higher than that (D.Wåge, Personal Communication, 2020). This can be problematic in many ways for both the utility company as well as the P2P community, especially if the microgrid is attached to the main grid, which in Norway's case it most likely will be. Gunnar gives the example of the following:

> When [the utility companies] are in need of doing maintenance in just the small street, they normally send messages to all the residents and say, we'll shut down the power within these times. Then they do this and go out and do their work and then normally it comes back on time. The problem is what if one of those homes is producing energy? And the guys from the company are down in the ditch trying to mend some cables and there is energy flowing through. Then there is a problem. So they also have to have

> control over the people who are producing…. They need a stop switch. (G. Crawford, Personal communication, July 29, 2020).

This highlights the problem in terms of a P2P network being able to disconnect from the grid and operate on their own, or in 'island mode'. In this case, the utility company would need to stay involved for safety reasons. Wåge also comments that the system in Norway, in regards to distributing energy, requires a permit that says you can transfer energy through cables, however, there is only one company in each area that is allowed to have this. In Stavanger's case it is Lyse because they hold a monopoly over the distribution grids.

In relation to balancing, in Norway, you are not allowed as a prosumer to produce too much energy and if you do, this causes problems and a license will be required (G. Crawford, Personal Communication, July 29, 2020). According to Inderberg, Tews and Turner, as a prosumer in Norway, you cannot deliver more than 100kW of energy back into the grid at any given time (2016). If you do, the balance of the system is at risk. If there are too many prosumers putting excess energy back into the grid, the grid may risk having too much energy and the utility company would then be in charge of trying to balance it out again (D. Wåge, Personal Communication, July 30, 2020). However, according to interviewees, even though you are not allowed to sell your excess energy for profit, you are allowed to feed it back into the utility grid for other benefits in return. Instead of profit, it would be sort of a backrolling system where you may get a few kroners off of your next electricity bill, or of the similar sorts. This is required by Norwegian law. Crawford comments that it is difficult to know as a prosumer how much you can produce and where this threshold is as there is a very small gap. Therefore, Norwegian law suggests that procedures need to be put in place where "DNO's can influence the activity of these distributed communities to help meet network needs" (THEMA, 2019).

On the other side of balancing, it should be noted that if a P2P microgrid community is just equipped with solar panels as their source of generation, in the winter time given the weather of Norway, they may not be able to produce as much as they consume. Therefore, according to Wåge, the grid operators act in a way as an 'insurance company', and corrects the frequencies and allocates the needed energy to consumers.

Another barrier to the establishment and operation of a blockchain based P2P energy system would be the licencing requirements in Norway. As mentioned previously, there is no current regulatory or market place for peer-to-peer energy trading to occur in Norway. It is illegal at this point in time to sell electricity to your neighbor. Interview respondent Gunnar Crawford highlighted that the municipality is in a stage with projects where they are trying to find a common ground with the Norwegian law in regards to energy production and taking on a more active participant role. However it is very difficult, and very unlikely to change any time soon. According to the NVE report regarding local energy communities, any community that operates a distribution grid of 22 kV or below, would likely require an Area Licence as well as a Trading License (2019). An Area license is "a general licence for electrical distribution network installations in a specified area" (THEMA, 2019). Under these regulations, a system comprising three or more houses would likely exceed the voltage boundary and require this license (THEMA, 2019). In addition, a trading license would also be necessary for such a P2P network and place quite a few responsibilities on the community (THEMA, 2019). Such obligations would include things such as the reporting of data to the NVE, a revenue cap set by the NVE, network tariffs, ensuring the quality of supply, as well as carrying out and reporting meter and billing data to norwegian data hub, Elhub, amongst many others (THEMA, 2019). It was however discussed and backed up by regulation literature that all the associated costs and effort it would require in order to acquire the necessary licensing would be quite unattractive to the small scale community actors (THEMA, 2019). The purpose of the blockchain based P2P system is to feel independent and deal with your energy needs on your own, however, given the current regime regulations today, it seems very far away that decentralisation can actually occur to the extent that it is already technologically possible.

Another obstacle in regards to the implementation of a P2P energy system would be assets and ownership control. According to Dagfinn Wåge, Lyse currently holds the monopoly of the distribution grid. With that being said, the distribution lines belong to them and if a microgrid community wanted to connect, it would really pose a problem of well, does the utility company own the microgrid or does the local energy community act as their own independent entity? Who owns the data? A Lot of important factors would have to be sorted out in order to add value of incentive to both parties involved. This becomes a problem for implementation of such a local energy system as there are less incentives from the utility side to want to partake in a project that ultimately takes more than it gives to them. Gunnar Crawford refers back to the monopoly situation and notes that Stavanger and the Kommune actually own a large part of Lyse. Therefore, it wouldn't be very smart to create competition and compete with your own company. Lyse knows that if they were to expose their technology to systems like this, there would definitely be competition. According to Crawford, with all the excess energy that would be making its way to Lyse's grid, Lyse would be the one responsible for doing all the bailouts and maintenance and what have you, without really getting paid for it anymore. So if they aren't getting paid for it, why would they really do it? They wouldn't. (G. Crawford, Personal Communication, July 29, 2020).

Grid Tariffs and Investments would be another potential barrier for a blockchain based P2P energy system. One of the bigger concerns from the interviewees was in terms of investments to the monopoly company, Lyse. If there are other entities generating electricity, then who is going to make the investments in the electric grid? The NVE also expresses that in terms of grid tariffs, it will prove to be very challenging to introduce a new tariff that "differentiates between the distribution of locally-produced electricity and electricity imported from the transmission system" (THEMA, 2019).

Finally, the most discussed barrier in terms of hurdles to implementing and operating a blockchain P2P energy trading system utilizing microgrids, is the lack of a good business model. According to Dagfinn Wåge, there has simply not yet been a presentation of a case that has inclined change on the utility side. He has been in various connections with start-ups and projects such as the one Antorweep Chakravorty is leading. He challenged them to come up with the good business case, but that has yet to come. With that being said there is still movement and discussion internally going on between prominent stakeholders. However, a strong business plan with valuable incentives to those involved has not yet arised. With that being said, Wåge states that when the time comes, if they (Lyse) are presented with a good business case, that incorporates them in a meaningful way, of course they would look at it. However, until then, given the regulatory learning curve that needs to occur in order to fully understand where systems like this fit into the energy sector, it could be a long journey. The interviewee suggests a possible five to ten years until possible change. The respondent from Lyse highlighted that ,*"a big ship takes a long time to turn" (Personal Communication, July 30, 2020).*

From the theoretical lens of the Multi-level perspective, it seems as though a system change from a complete monopoly of the electricity grid, to allocating a place for blockchain and P2P energy markets is still far from happening. To put the theory into perspective, the regime in this study is the utility company Lyse who currently still maintains a monopoly over the electric grid. The niche is then the blockchain facilitated P2P energy trading platform, as well as for reference, the start-up company bitYoga. Leaving the landscape as the various pressures and world views surrounding environmental sustainability and active energy participants that influences niche and regime dynamics (Geels, 2011). According to Hildingsson (2014), such a theory constructs that changes within a society happens in a very organic and evolutionary manner, suggesting that it is an integrated whole and always adapting to new conditions.

Currently the niche decentralized system is still in a very pre-development phase. There is still lack of valid business cases, and still areas of concern regarding regulations. Therefore, the niche is still in a place of experimentation and nurturing of the new innovation.

However, the landscape suits the niche well, especially in Norway. With such a strong environmental drive from the citizens, as well as desire to own and be independent, a niche technology like such stands quite a chance. Even though the innovation is still in a pre development stage, it was clear through the interviews and case studies that the regimes on a global level are beginning to feel the pressure and beginning to consider ways that they can remain prominent players in a rapidly developing technological environment.

According to the MLP, such a drastic change is not going to be a linear process, rather it is going to experience ups and downs and evolve over time (Hildingsson, 2014). The niche and regime are going to challenge each other and try to take each other down. The niche market surrounding P2P energy markets is really gaining momentum these past few years as seen in case studies, however, the regimes are very deep structure locked-in and difficult to penetrate (Geels, 2010) Especially in Norway, given the lack of incentive for pursuing such a new energy innovation, it may be more difficult and take longer to enact change than in other places of the world where there may be more incentive. However, pressure is continually increasing and from an MLP lens, eventually, not necessarily any time soon, it is likely that a transition will occur in which citizens get to play a more active role in the energy market.

9. Suggestions and Conclusions

My initial hypothesis in regards to implementing blockchain technology as a platform for P2P energy trading utilizing microgrids, was that the Stavanger Smart City would be an exemplary environment to administer such an advanced concept and technology. However, through case study analysis and semi-structured interviews with various members of the community from the Stavanger Kommune, the main utility company Lyse, and the CEO of a blockchain focused start-up company called bitYoga, the results were not quite in line with what was originally predicted. Even though Stavanger is one of the most advanced energy hubs of the world, a P2P energy market still proves to be many years away from becoming a reality for its citizens. In terms of being a valid concept, it was fair to gather that a technological system like this can work. From a technological standpoint, it has been accepted and conceptually, it is understood and known in terms of how it can be applied to various aspects of our life. The greatest problem lies with the immaturity of the technology and therefore lack of a quality business case to be worked towards. If there were a good business case presented, more prominent stakeholders would be likely to partake.

The concept of a blockchain based peer-to-peer energy market is something that has excited many on a global scale, and plenty of research and energy is continuously being poured into finding the best place for it within the energy sector. However, when it comes to Norway, the country's energy is already supplied by majority of renewable energies, hydropower to be specific, therefore, the incentives and triggers are much different than other countries in terms of immediate desire to partake in the blockchain P2P microgrid movement.

Therefore, for future suggestions, it could be beneficial to take an approach as was taken in the Brooklyn Microgrid case study. A 'regulatory sandbox' alternative can be taken on in order to get a feel for the regulatory framework surrounding the energy sector and P2P trading, blockchain and microgrids, while still being able to move forward with the development. This would be beneficial to the regulators as they would not have to commit to altering the laws and can instead wait and see. Technologies at this stage of the 21st century are evolving so quickly that making amendments and changes to regulations can seem a bit unnecessary or premature.

A final comment regarding what was derived from the interviews was how Norway could start applying a P2P system while staying within the regulatory framework. According to respondents, a potential first step in the right direction for Norway in terms of getting to a place like the study suggests would be to possibly consider looking into storage systems. Rather than incentivising a system based off of money, it could be more plausible if the community was self-sufficient and that was in a way the selling-point of living in such a neighborhood. This could be an interesting future study.

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Appendix: Adapted and Averaged Interview Guide

1. What is the Smart City's priority in regard to how you want to use electricity in Stavanger?

2. What has your team's experience been in regard to introducing new technologies to the community? How have you addressed the adoption process? Have there been difficulties or obstacles you have faced?

3. Do you think more community citizens would interact and implement smart projects into their own everyday lives if there were monetary incentives?

4. I have noticed that the Smart City project CityZEN utilizes blockchain technology. How is that experience progressing? Any difficulties with the technology platform?

5. What do you think of the relationship between renewable energy and blockchain technology?

6. Peer-to-peer energy trading arguably has the potential to transform the current energy system. Do you see a potential for implementing such a concept into this city's community? Based on your experience, how do you think the community would react?

7. Norway's energy mix is approximately 98% renewables. With that being said, average citizens are not at the moment responsible for producing any of that on their own. With the smart city goal of coming together and becoming smarter, do you see peer-to-peer energy trading as well as micro-smart grids as a promising future project?

8. What is your opinion on citizens participating in the energy market rather than being simply passive consumers?

9. Through the use of blockchain technology, decentralization is achieved, therefore eliminating a middle man such as a bank. Making transactions between individual community members becomes faster and more efficient, while also allowing for prices of energy to be set and bought at more affordable prices. Do you think this is something that would better satisfy the people of Stavanger?
10. In your opinion, are there any obstacles for establishing a decentralized energy market?
11. Do you think there would be any political difficulties if microgrids and peer-to-peer energy sharing was established throughout the Stavanger community?