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Advancing blockchain:

A case of blockchain-enabled residential P2P electricity trading

Abstract: Moving towards decarbonization, the energy sector is facing a challenge of incorporating an increasing number of renewable energy sources generators in the existing electricity system. One of the proposed solutions is the adoption of *blockchain-enabled residential P2P electricity trading*. It demonstrates a new way of electricity trading, which allows for a greater transparency, automatization, leading to a democratized energy market with less CO2 emissions. However, many unsolved questions result in an increasing number of researchers to focus on the application of blockchain in the energy sector while focusing on multiple use cases, including *blockchain-enabled residential P2P electricity trading*. Yet, a research gap remains when trying to identify how *blockchain-enabled residential P2P electricity trading* can advance and essentially be adopted in the mainstream. Taking the theoretical lens of the business ecosystem approach combined with the innovation-decision theory, we aim to identify who is driving the change and assess the role of other relevant actors for this innovation to advance. This master thesis is a single-case study examining the phenomenon of *blockchain-enabled residential P2P electricity trading* in the context of its business ecosystem. Adopting a qualitative approach, we extensively researched the existing academic literature, other secondary data, and conducted three observations and 26 in-depth and semi-structured interviews with experts in the field of energy, blockchain or a combination of these. The following four findings of this study evolve around the identified *blockchain-enabled residential P2P electricity trading ecosystem*. (1) The four relevant actors in this ecosystem are startups, utilities, consultancies and technology providers, and institutional actors. Their interactions are fundamental for the advancement of the innovation. (2) The identified interactions create interdependencies which lead to the fact that none of the actors can act alone to advance the innovation. (3) Startups are driving the innovation. (4) Utilities and institutional actors have the power to halt the advancement of the ecosystem and hence this innovation.

Keywords: blockchain, energy sector, energy decentralization, peer-to-peer electricity trading, ecosystem

Supervisor: Peter Popovics

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Glossary and Abbreviations

Blockchain-enabled residential P2P electricity trading (BRET): buying and selling electricity among residential consumers and prosumers through a blockchain-based platform

German Energy Agency (DENA): a private company "established by the Federal Minister of Economics and Technology in September 2000 to implement the measures in the Climate Protection Programme" (IEA, 2015; para.11)

Distribution: here, refers to electricity distribution: the process of delivering electricity to the residential customers

Peer-to-peer (P2P): a decentralized type of interaction where third party intermediaries are not needed

Energy Web Foundation (EWF): EWF is a consortium which consists of multiple energy incumbents, startups, technology providers and they are working on creating the Energy Web as a blockchain for P2P trading (EWF, n.d.b)

Grid Singularity: A German startup that "is a green blockchain technology company, leading the development of an open, decentralised energy data exchange platform" (Grid Singularity, 2018; para.1).

Hybrid solution: a solution combining blockchain with another technology

International Energy Agency (IEA): the world's leading energy authority

International Renewable Energy Agency (IRENA): "an intergovernmental organisation [supporting] countries in their transition to a sustainable energy future" (IRENA, 2018; para.1)

LO3 Energy (LO3): an US-based startup which "is developing blockchain based innovations to revolutionize how energy can be generated, stored, bought, sold and used, all at the local level" (LO3 Energy, 2018; para.1)

Microgrid: "A microgrid is an ecosystem of connected prosumer and consumer energy assets. Energy is generated, stored, and transacted locally, creating more efficient, resilient and sustainable communities." (Brooklyn Microgrid, 2019; para.5)

Photovoltaic panel (PV): renewable energy source generator most commonly adopted by prosumers

Prosumer: here, refers to residential energy prosumers, an individual who consumes energy but also produces it through, e.g. photovoltaic panels

Regulations: a set of policies, laws and industry-specific rules designed by institutional actors to regulate behavior (in this paper also referred to as institutions)

Regulatory sandboxes: exceptions from regulatory-compliance granted to specific projects by the institutional actors

Renewable Energy (RE): electricity that is generated without causing sources being depleted

Renewable Energy Sources (RES) generator: a generation capacity producing electricity from sources that are not being depleted in the process, e.g. rooftop photovoltaic power station

Smart contracts: “A set of conditions recorded on the blockchain, so that transactions automatically trigger when the conditions are met.” (Carson et al., 2018; para.9)

Swedish Energy Agency: a Swedish “government agency [that aims] to create a sustainable energy system that combines ecological sustainability and competitiveness” (TheHub, n.d.; para.1)

Utility / Incumbent: Here, refers to electricity producers, distributors and retailers

Wholesale electricity trading: trading that occurs between utilities, brokers, marketers and potentially also industrial customers who consume high volume of energy. It is one step before the energy is delivered and paid for by the customer.

1. Introduction

This chapter presents the background to the research topic and the problem statement. The purpose and research question will be introduced as well as the delimitations of this study. Finally, the disposition of this study will be given.

In 2015, 195 countries signed the Paris Agreement by which they committed to reduce their greenhouse gas emissions (EEA, 2016) "as soon as possible" (UN, 2015; p.4). Energy alone contributes to the total global CO2 emissions by 60% (UN, 2010). Yet, in 2018, global energy demand still rose by 2.3%, the highest growth in a decade (IEA, 2019a), which corresponded to a 1.7% CO2 emission increase from 2017 (IEA, 2019b). Specifically, the global electricity demand even rose by 4%, representing the highest growth rate for eight years (IEA, 2019b). Currently, 65.1% of the produced electricity is based on fossil fuels (IEA, 2019c), which is responsible for an overwhelming majority of CO2 emissions within electricity generation.

To reduce the CO2 emissions caused by fossil fuels, increased deployment of renewable energy sources (RES) are crucial (IEA & IRENA, 2017). In 2018 alone, the renewables-based electricity generation increased by 7% worldwide, while the greatest increase originated from solar PV and wind electricity generation (IEA, 2019b). However, connecting an increasing number of RES generators brings a new kind of challenges. First, the grid was originally designed to deliver energy in one direction, i.e. from large-scale power plants to the consumer. In contrast to the large-scale power plants, solar PV and wind RES generation fluctuates in voltage and frequency, which can challenge the reliability of the grid (Steen et al., 2014). Second, the matching of supply and demand over time represents a problem. While large-scale generation can be scheduled to adapt to low and peak hours of electricity consumption, RES generation varies during the day and is often high when the consumption is low. This means that most energy is generated during daytime when the 'sun is shining' but the residential consumption is low. Whereas little or no electricity is produced during the residential consumption peak hours which are usually during evening when most people are home. Consequently, the growing adoption of RES, both at residential and large-scale, pressures the utilities, who operate the grid, to find a solution that could offset the surplus (overloading) and lack (underloading) of energy over time to avoid power outages (Yu et al., 2018).

Furthermore, there are more challenges that the current electricity distribution system is encountering. First, a centralized electricity system cannot scale the integration of all electricity producers, number of which is increasing due to the emergence of many prosumers, who are producing and consuming energy usually via self-installed solar PV (Zhaoyang et al., 2018). Second, the centralized electricity grids work inefficiently and led alone in Sweden in 2017 contributed to transformation and distribution losses[1] by 27 TWh, equivalent to 4,7% of the energy supply (Swedish Energy Agency, 2019). Part of that loss stems from the long distance between the source and the consumer due to the resistance. Finally, according to the UN, the electricity infrastructure built in the 1960s and 1970s in Europe is starting to "reach the end of their economic lives" (UN, 2010). Therefore, a solution must be found that is not only solving the current problems but taking a step further to build a system that would be operational and sustainable for the centuries to come (Bringault et al., 2016). Therefore, this study will focus on innovation and its diffusion in the energy sector.

Many trends in the energy sector have emerged, while the most prominent ones are electrification, decentralization and digitalization (WEF, 2017). For example, the ongoing digitalization facilitates grid management and optimizes energy production. Especially the new technologies and innovations have the potential to disrupt the traditional energy models (WEF, 2017). These technologies are for example IoT devices such as smart meters or blockchain that various actors are currently experimenting with. With blockchain promising many benefits, it is is important to investigate whether it could solve the energy trilemma: a trade-off between energy cost reduction, energy security and environmental sustainability (Andoni et al., 2019).

Blockchain is a distributed, ledger-shared database, that is immutable (Zhaoyang et al., 2018). It enables the reduction of transaction costs and removes the need for trust that would be provided by a third party (Carson et al., 2018; Sawa, 2019). This is due to the fact that blockchain is operating in a decentralized and autonomous way. This decentralization plays an important role as it allows the trend of decentralization within the energy transition. It sets the stage to include more actors in the system and make them an active party, thereby remedying the aforementioned limitations of the current centralized electricity trading system. Additionally, blockchain can add great value in many fields within the energy sector, e.g. guaranteeing transparency, billing and financing (Yu et al., 2018).

Within the energy sector, blockchain's potential has just started to be realized as demonstrated by the increasing number of startups, projects and use cases (Andoni et al., 2019). Moreover, the blockchain application in the energy sector is neither widely developed nor researched on

[1] Excluding energy loss in nuclear generation, e.g. for cooling for the reactors.

(Andoni et al., 2019), representing the importance and novelty of its investigation. Blockchain can be applied in various areas within the energy sector, which is currently explored through many use cases. Residential P2P trading represents a decentralized design of the electricity market and is the area in which blockchain-enabled services would fit most naturally in as it allows electricity trading among prosumers and consumers, who can therefore control their generation and demand (Andoni et al., 2019). According to a Gartner report in 2017, blockchain as a key platform-enabling technology has passed its hype phase and will be able to make a dramatic and transformative impact within the next three to eight years[2] (Gartner, 2017). Therefore, it is important to investigate how blockchain will advance in the energy sector. With the emergence of consortia, such as the Energy Web Foundation (EWF), that focus on implementing *blockchain-enabled residential P2P electricity trading*, it seems to be increasingly relevant to aim attention at the interconnectedness of actors in this context.

1.1. Purpose and research questions

The purpose of this study is to understand how blockchain will advance within the energy sector, specifically *blockchain-enabled P2P residential electricity trading* (hereinafter referred to as BRET). By advancing, we refer to further diffusion and adoption of BRET in the energy sector. We argue that the existing interactions between relevant actors are crucial for the advancement and need to be further analyzed. Therefore, we use the ecosystem approach in combination with the innovation-decision theory as our theoretical lens to analyze the adoption of BRET and the dynamics of the interdependence of the relevant stakeholders. Therefore, this study aims to answer the following research questions:

Q1: What are the key factors determining the advancement of BRET?

Q2: How and why do the key actors interact in the context of advancing BRET?

[2] The Gartner report was written in 2017, hence we deducted two years from the original assessment of five to ten years.

1.2. Delimitations

Due to our focus, expertise and discipline, we do not focus on the purely technological aspects of either blockchain or the electricity system. The understanding of those is mainly a means to comprehend their implications to BRET from the business standpoint. Hence, we delimit ourselves to the business aspect and look at actors' interaction among each other, factors influencing it, and their business motivation. The discussed blockchain solution, BRET, is delimited to the existing market and the way electricity is traded while drawing on the implications of the blockchain technology.

Furthermore, the focus of this study is BRET. Residential P2P electricity trading is expected to play an increasingly important role (Andoni et al., 2019) and also sets the stage for blockchain to have long-term impact in the energy sector (Brilliantova & Thurner, 2018). Therefore, we delimit ourselves from studying blockchain-enabled wholesale electricity trading or P2P electricity trading without blockchain as this is out of scope of this study.

Lastly, we delimit the geographical scope to the European context due to the specificity of the technological, regulatory and competitive landscape. This led us to focus on stakeholders operating in Europe. When interviewing companies based outside of Europe, we focused on their strategy and impact that they want to achieve in this region.

1.3. Disposition of the upcoming chapters

This study consists of six main sections. The *Introduction* provides the background and purpose of this research. The *Literature Review and Theoretical Framework* aim to give the reader the foundation to understand the upcoming discussion by reviewing the specificities of the energy sector, the blockchain technology, its application within the energy sector and the theoretical framework. Subsequently, the *Methodology* outlines what and why this approach has been taken and what data were used. Thereafter, the *Empirical Findings* are presented, followed by the *Discussion*. Finally, this study ends with the *Conclusion* of the key findings, implications and suggestions for future research.

2. Literature Review and Theoretical Framework

This section discloses what is known about the researched topic. First, the energy sector and the blockchain technology are introduced separately. Second, these two areas are merged to explore what is known about the blockchain application within the energy sector. Third, the research gap is presented. Lastly, based on the existing literature and identified research gap, we will introduce the ecosystem concept by Moore, which will be expanded upon the innovation-decision process.

2.1. Energy sector

2.1.1. Electricity value chain

The electricity value chain consists of several steps (figure 1). In many cases, the electricity producers, distributors and retailers form an integrated value chain, which means that they are responsible for the generation, distribution, retailing and service provision to the customer. For the purpose of this study, they will be referred to as utilities or incumbents.

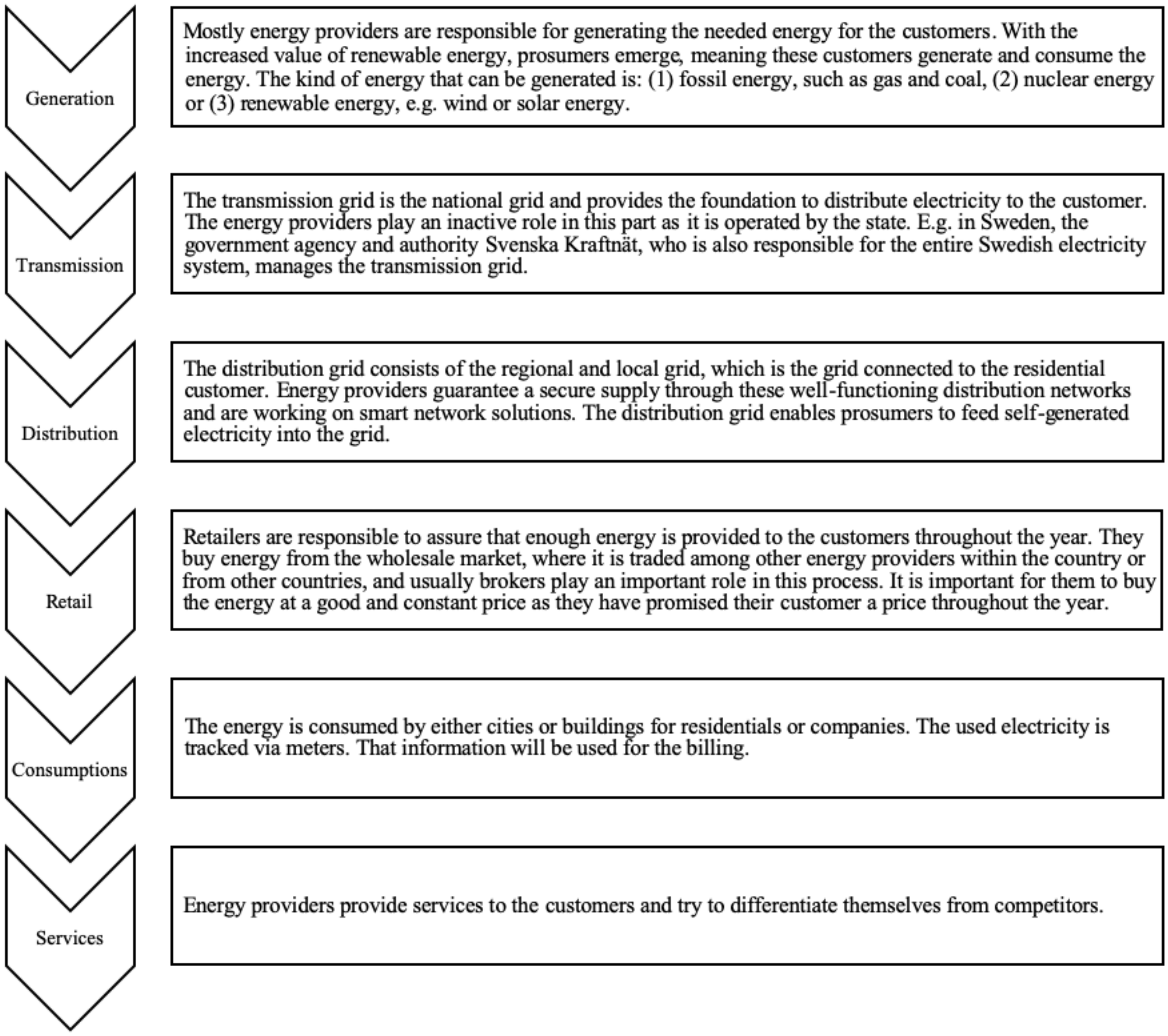

Figure 1: Electricity Value Chain (based on Vattenfall, 2018a; Vattenfall, 2018b; GE, 2016; Nordling, 2017)

2.1.2. Trends in the energy sector

Three major trends in the energy sector were identified by the WEF (2017) that will have potential to fundamentally disrupt electricity systems: (1) Electrification, (2) Decentralization, and (3) Digitalization. Electrification shifts end-consumers away from using fossil fuels towards RES generation and usually increases energy efficiency. Decentralization is driven by the decrease in cost of distributed energy resources and allows the customer to play an active role in the system in accordance with coordination. Common technologies are, e.g. microgrids and solar PVs. Lastly, digitalization enables open and automated communication and operation of the system at real time. This can be divided in network technologies, such as smart metering, and technologies beyond the meter, e.g. IoT (WEF, 2017). Vattenfall refers to these market trends in its group presentation 2018 as well, demonstrating the significance of those (Vattenfall, 2018a).

2.1.3. Microgrids

As mentioned, microgrids are one of the key technologies of decentralization within the energy sector (WEF, 2017). "Microgrid energy markets allow small-scale participants, i.e. consumers and prosumers, to actively trade energy[3] within their community in (near) real time" (Mengelkamp et al., 2018; p.870) (figure 2), which is classified as P2P electricity trading. Microgrids functions if the participants are physically connected, but also when only virtually.[4] The electricity transactions are classified in three processes: (1) identity verification,[5] (2) market opening and (3) market closing (Wang et al., 2017). Usually, a trusted third party, e.g. the government, authorizes the new participant, which is executed by a software program (Wang et al., 2017). Microgrids work in two modes: (1) while still being connected to the main grid, (2) in the island-mode when they disconnect (Prete & Hobbs, 2016).

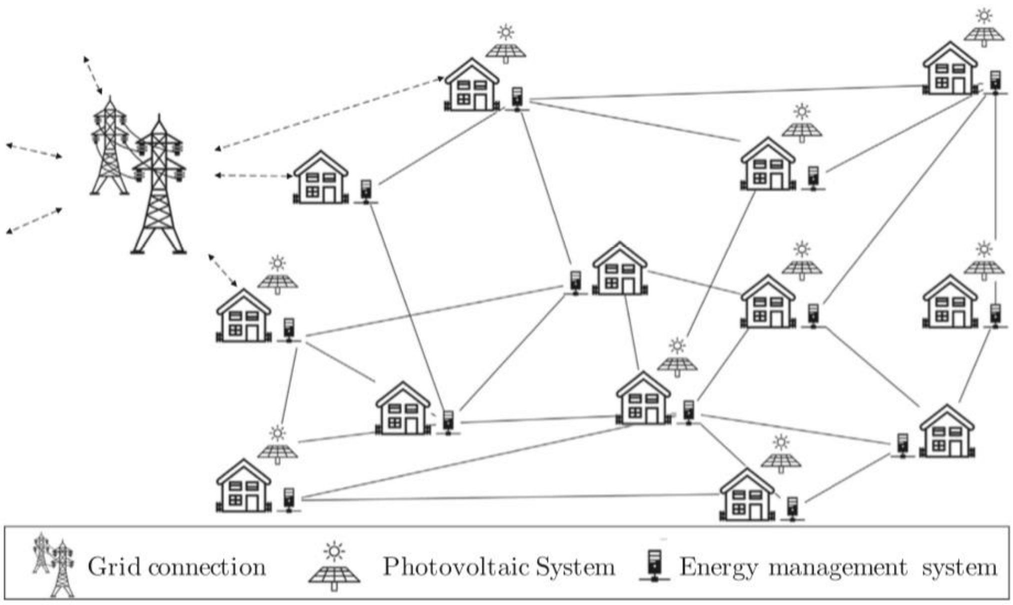

Figure 2: An exemplary microgrid setup (Mengelkamp et al., 2018a; p.872)

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[3] Communities or individuals can produce their own energy e.g. via solar energy systems or wind turbines (Deloitte, n.d.).

[4] "Virtual microgrids are the aggregated control of multiple energy producers, prosumers, and consumers in a virtual community." (Mengelkamp et al., 2018a; p.871)

[5] To assure whether the participant has the right to engage in those market transactions (Wang et al., 2017)

Compared to the traditional centralized transactions mode, the microgrids have lower electricity losses, distribution and transaction costs (Wang et al., 2017; Deloitte, n.d.; Mengelkamp et al., 2018a). This is due to the fact that they allow the local consumption of RE, thereby avoiding long-distance transmission of electricity, hence reduce electricity loss in terms of transmission and distribution (Wang et al., 2017; Kamel et al., 2010; Mengelkamp et al., 2018a). Moreover, the need for intermediate links is reduced, which diminishes distribution and transaction costs (Wang et al., 2017; Deloitte, n.d.). Being able to control demand response better, the capacity costs are also reduced (Deloitte, n.d.).

Moreover, microgrids improve reliability of supply since they offer another source of electricity e.g. in case of power outages by the grid (Prete & Hobbs, 2016). "[L]ocal microgrids can improve network resilience, provide ancillary services, such as frequency and voltage support, to aging power systems with the potential to defer expensive network upgrade investment. In addition, they can provide energy services to consumers in the case of grid contingencies" (Andoni, 2019; p.154). With all these benefits and the current trends, microgrids are becoming a relevant topic. When combining this decentralized solution with the digitalization trend, it is interesting to see who is part of that and how that potential disruption evolves.

2.2. Blockchain technology

For the purpose of this study, we adopt Carson et al.'s (2018) definition of blockchain as distributed and decentralized ledger that is depicting one type of a database technology. In effect, it is a "distributed network, where members, known as nodes, are connected to each other and hold equal copies of the ledger containing registers of the underlying digital good(s)" (Dick & Praktiknjo, 2019; p.5). By being decentralized, instead of the usual, centralized networks, blockchains enable a market platform without conflicts of interest as there is no information asymmetry for any market participant since every party is holding and controlling the transaction and the respective records (Mengelkamp et al., 2018a), (figure 3). This adds availability and resiliency with reduced redundancy since in case of any failure, the existing network is sufficient enough to continue running (Dick & Praktiknjo, 2019). Therefore, no central supervision is needed when including cooperation within such a distributed system (Mengelkamp et al., 2018a).

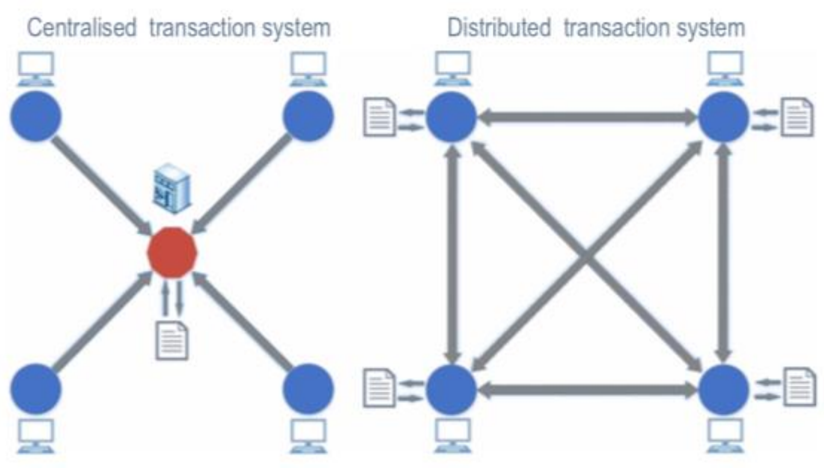

Figure 3: "Centralized and distributed transactional platforms: a single trusted authority manages the ledger as opposed to every member holding a copy of the ledger." (Andoni et al., 2019; p.146)

Blockchain provides "a transparent and valid record of past transactions that cannot be altered retrospectively" (Mengelkamp et al., 2018; p.208). Therefore, an actual blockchain consists of many blocks that are added after every transaction (Zheng et al., 2018). The way a new block is validated among the other participants before it is added to the chain depends on the specific consensus algorithms (2.2.1.; 8.1.2.) (Zheng et al., 2018). These kinds of transactions can also be programmed via smart contracts (2.2.2.; 8.1.3.) (Carson et al., 2018; Zheng et al., 2018). Moreover, it depends on the specific blockchain platform,[6] who is part of the blockchain (8.1.1.). In this study, we discuss only a permissioned consortium platform. The different types of blockchain are discussed in 8.1.1.

2.2.1. Consensus algorithms

The consensus algorithms[7] are the foundation of blockchain as they determine how the different transactions are validated, hence how the information is accepted to be part of the blockchain (Andoni et al., 2019; Dick & Praktiknjo, 2019). Depending on the chosen algorithm, "the scalability, transaction speed, transaction finality, security and spending of resources such as electricity" differs (Andoni et al., 2019; p.147).[8]

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[6] It can be many people, who do not know each other and do not need any permission to be part of that system, up to a few people, who all know each other and need permission to be part of the platform (Carson et al., 2018; Zheng et al., 2018)

[7] For a detailed explanation, see 8.1.2.

[8] Additionally, it determines which validator nodes will be part of the decision, which can be all or just a few.

Different types of algorithms exist. This study will only focus on proof-of-work, proof-of-stake and proof-of-authority while the most relevant consensus algorithm for this study is proof-of-authority since it currently proves to be favored by several utility companies within the energy sector (Andoni et al., 2019)**.**[9]

2.2.2. Smart contracts

Smart contracts[10] are invaluable when using a blockchain platform (Wu & Tran, 2018), especially when trading at a P2P level. It is a computerized transaction protocol that facilitates trading since a program is coded to honour an agreement by executing the contract when certain conditions are met (Andoni et al., 2019; Zheng et al., 2018). This allows automatic trading without any real human interaction or intermediary while being tamper-proof and self-enforceable (Andoni et al., 2019). The benefits of this kind of trading include: (1) removing of intermediaries, (2) reducing of costs for transacting, contracting, enforcement and regulatory compliance (3) increased efficiency of low-value transactions[11] (Andoni et al., 2019).

2.2.3. Maturity

Currently, many different types of blockchain platforms[12] exist and no technical standard has been set on the market while there is disagreement whether a clear standard needs to be set and what features such a standard would even need to contain (Ingram et al., 2017). However, according to Carson et al. (2018), a set standard is needed once more companies are involved in a blockchain application. Moreover, they also argue that a common problem in many blockchain use cases is the anxiety towards feasibility due to several reasons, such as scalability based on the fact that the technology is immature (Carson et al., 2018).

According to Gartner (2017), blockchain has surpassed the hype phase (figure 4), i.e. the peak of inflated expectations, and is now at the threshold to enter the trough of disillusionment, hence is an immature technology. Nevertheless, it was already identified as a crucial platform-enabling technology that will change the current perception of IT realities (Gartner, 2017). Its

[9] Therefore, we neglect algorithms such as Delegated Proof of Stake (DPoS), Proof of Burn (PoB) or Proof of Capacity (PoC) and others (Andoni et al., 2019).

[10] For a detailed explanation, see 8.1.3.

[11] Under the assumption that blockchain provides the compatibility among the used transaction systems

[12]E.g. Bitcoin, Corda, Ethereum, Hyperledger, Tobalaba

potential to make a transformative and dramatic impact is estimated to happen within the next three to seven years[13] (Gartner, 2017). More optimistically, Panetta from Gartner claimed that the core technology issues will be solved within the next three to five years and will allow for blockchain solutions that are promised now[14] (Panetta, 2019).

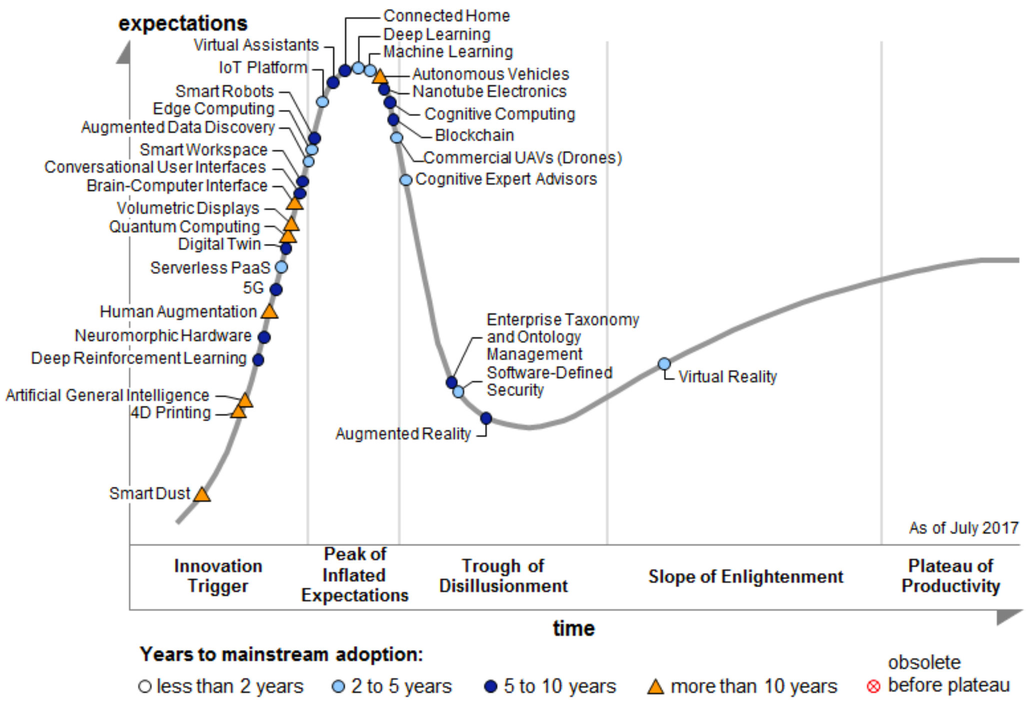

Figure 4: Hype Cycle for Emerging Technologies, 2017 (Gartner, 2017)

With continuous development, blockchain will be able to create transformative business models, thereby enabling entirely new revenue streams (Carson et al., 2018).

2.2.4. Benefits of blockchain

Carson et al. (2018) identify blockchain's core advantages and list "decentralization, cryptographic security, transparency and immutability" (Carson et al., 2018; para.11). Another main benefit is the enablement of trust as a third-party intermediary, that is usually a central authority and not necessarily always trusted, which is removed (Mengelkamp et al., 2018b). By removing the need for an intermediary, information can be easily verified and value can be

[13] The Gartner report was written in 2017, hence we deducted two years from the original assessment of five to ten years.

[14] E.g. decentralization and tokenization (Panetta, 2019)

exchanged as the dependence on a third party is eliminated. An important benefit of blockchain is that there are multiple opportunities on how to set up the blockchain platform, thereby enabling a variety of configurations that can be individually adjusted for specific objectives and commercial requirements (8.1.1.) (Carson et al., 2018).

2.2.5. Challenges of blockchain

Technology maturity and regulations were identified as the major challenges for blockchain adoption (Brilliantova & Thurner, 2018). The maturity issue (2.2.3.) results in poor performance of the application, difficult integration in the existing systems, scalability issues and faces high development costs (Brilliantova & Thurner, 2018; Andoni et al., 2019). Moreover, regulations depict a major obstacle (Deloitte, 2016; Andoni et al., 2019) as blockchain is so novel that there are no general regulatory treatments identified (Brilliantova & Thurner, 2018). Additionally, GDPR represents an important regulatory challenge as the privacy protection requires the removal of personal information at request. However, as a result of its immutability, blockchain is not designed for removing the data (Schwarz et al., 2018). Another common problem is the uncertain development of the industry, which results in a minimal adoption of blockchain (Brilliantova & Thurner, 2018). Depending on the chosen consensus algorithm, the vulnerability degree to malicious behavior, potential cyber-attacks, or collusion differs, yet still having a very high degree of cybersecurity (Andoni et al., 2019). Given the difficulty of that technology, a challenge is the awareness and understanding of blockchain and its functions, hence impeding investments and examination of ideas (Deloitte, 2016).

2.3. The application of blockchain within the energy sector

In many sectors, especially the financial sector, blockchain is considered to be an innovative ‘groundbreaking’ technology (Beck & Müller-Bloch, 2017; Albrecht et al., 2018). Within the energy sector, blockchain is becoming more popular and startups, as well as utilities, are investigating that technology to identify its potential for applications (Albrecht et al., 2018; Schwarz et al., 2018). Alone from Q2 2017 until Q1 2018, more than $300 million were invested in blockchain within the energy sector (Schwarz et al., 2018). When it comes to the perceived probability of the application of blockchain in the energy sector, a survey of the German Energy Agency (DENA) resulted in 60% of decision makers within energy companies responding that they believe that further dissemination is likely, 21% value this as a game changer for the energy supply sector, while 14% see it as niche application and 5% as small to non-existent (Burger et al., 2016). More specifically, they believe that blockchain can potentially reshape different aspects of their companies and even the entire energy market, especially considering process optimization and P2P transactions (Burger et al., 2016). It promises to automate processes, disintermediate, rethink value chains and provide the customers with more information to enable a wider choice of actions (Albrecht et al., 2018; Morabito, 2017).

2.3.1. The value of blockchain within the energy sector

When identifying the value of blockchain application within the energy sector, the best definition to use is the one stating that blockchain stores, legitimizes and executes P2P financial and business transactions immutably in a distributed ledger in real time as it demonstrates that it makes any middlemen or intermediaries, such as utilities, superfluous (Pöyry, 2017). New companies (startups) such as Grid Singularity[15] are entering the market to develop new areas of value creation, but also existing utilities such as Vattenfall or Fortum are testing the potential of blockchain technology (Pöyry, 2017). With the potential change of value creation, incumbents could act as the enabler for decentralized power grids (Pöyry, 2017). This opportunity is important as the entire energy sector is currently shifting towards a decarbonized, decentralized and digitized production and distribution (Brilliantova & Thurner, 2018). Michal Merz, Managing Director of Ponton[16], claims that when the energy sector is becoming more decentralized, a decentralized technology will be needed as well. Blockchain can be seen as a good tool for executing various business processes in the energy sector, managing IoT device transactions of e.g. smart meters and creating trust based on the emerging ability to prove the origin of energy (Pöyry, 2017). With that proof, information transparency is given, which reduces the potential of fraud (Donnerer & Lacassagne, 2018). Additionally, stemming from the shared economy principles and distrust of organizations, information transparency becomes increasingly important for customers as they want to understand and gain access of information of their purchases (Burger et al., 2016).

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[15] A German startup that "is a green blockchain technology company, leading the development of an open, decentralised energy data exchange platform" (Grid Singularity, 2018; para.1).

[16] Ponton is an IT service provider with most of their "activities aim[ing] at consortia from the energy sector with a focus on energy trading, grid management and customer-related processes" (Ponton, n.d.).

Besides enabling information transparency, blockchain has many more advantageous functionalities. First, it can facilitate the mobility and billing process without any intermediary, e.g. charging EVs[17] (Burger et al., 2016). Second, combined with smart contracts it can enable neighbors to buy excess energy from each other (Burger et al., 2016; Donnerer & Lacassagne, 2018). Third, using blockchain in the energy sector can also enable smart grid management, trade of green certificates, energy trade validation[18], real-time monitoring and analysis of energy use (Burger et al., 2016; Donnerer & Lacassagne, 2018). These types of process optimization through automatization and digitization will most likely lead to cost reduction within the incumbents and the grids[19] (Burger et al., 2016; Donnerer & Lacassagne, 2018). Using cryptocurrencies within the energy sector can lead to potentially avoiding high inflation rates[20] since many use cases back the value of the currency by energy, which is the case of SolarCoin,[21] thereby incentivizing ecological values and environmental protection (Burger et al., 2016; Clapaud, 2016).

2.3.2. An outlook of the possible future energy system

It is important to identify where blockchain can be applied in the energy sector to be able to assess the potential diffusion of blockchain. Pöyry and DENA have identified such areas in the value chain of energy (Burger et al., 2016), which was illustrated by Pöyry (2017) (figure 5).

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[17] E.g. BlockCharge is an app that promises worldwide authentication, charging and automated billing, including negotiation and payment, for EVs without an intermediary (Burger et al., 2016).

[18] The first three are parts of Grid Singularity's vision, an Austrian startup (Burger et al., 2016).

[19] "Blockchain has the potential to reduce grid costs through better balancing, reducing metering costs, making information streams faster and more immediate, and adding customer value through more detailed and transparent information about energy origin and evolution" (Burger et al., 2016; p.24).

[20] A startup in South Africa, called Bankymoon, introduced smart prepaid meter with cryptocurrencies, ensuring utilities to receive their value for energy on time and consumers to not be affected by high inflation as cryptocurrencies, such as Bitcoin, are not linked to local currencies (Burger et al., 2016)

[21] SolarCoin is even rewarding the usage of renewable energy. By proving your solar photovoltaic installation, you receive SolarCoins when registering into the (Kastelein, 2016).

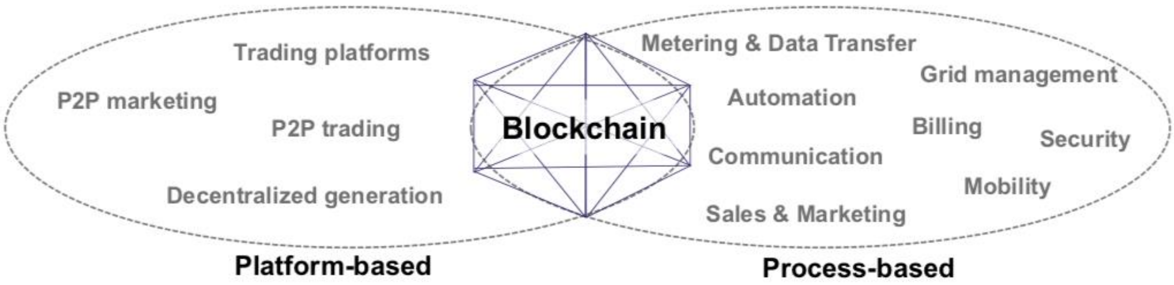

Figure 5: Point of contacts and opportunities of blockchain in the value chain of energy (Pöyry, 2017; p.6)

Andoni et al. (2019) were the first academic scholars to present a peer-reviewed study regarding a systematic overview of blockchain activities in the energy sector, which is demonstrating the novelty of this research field. They have identified the same aspects in the energy value chain that will be affected by blockchain as Pöyry and DENA. Additionally, they determined potential in smart grid applications, identity management, sharing of resources and competition as relevant operation and processes (Andoni et al., 2019). Blockchain changes these operations and processes (8.2.1.) while creating new opportunities that can lead to an entirely new energy system allowing and supporting decentralized energy (figure 6). Classifying P2P trading as the true form of decentralized energy, Andoni et al. (2019) describe residential P2P electricity trading as "an application domain where blockchain-enabled systems would fit most naturally" (p.154). Such applications can be usually accomplished within microgrids or small community projects (Andoni et al., 2019). Additionally, the strongest long-term impact of blockchain in the energy sector is considered to be the enablement of P2P microgrids (Brilliantova & Thurner, 2018). Therefore, the following sub-subsection will exemplify the application of BRET in microgrids.

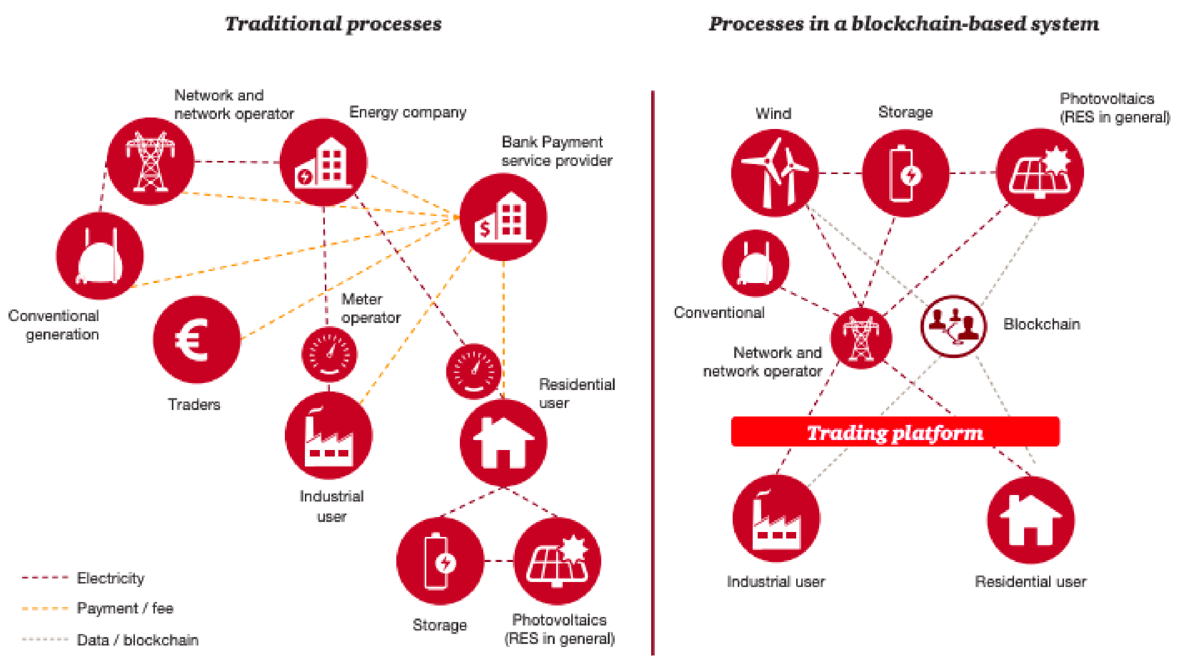

Figure 6: Transformation of market structures on introduction of decentralized transaction model (PwC, 2016; p.18)

BRET in microgrids

Wang et al. (2017) have illustrated how blockchain would be applied in microgrid electricity transactions (figure 7). The needed identity verification in microgrids (Albrecht et al., 2018 [22]) can be achieved through blockchain, therefore removing the need of a third party (Wang et al., 2017). The most suitable blockchain for BRET in microgrids is consortium or private (Albrecht et al., 2018; Brilliantova & Thurner, 2018) with proof-of-authority as the consensus algorithm (8.1.2.) (Andoni et al., 2019). Moreover, thanks to smart contracts, the participants can easily trade electricity depending on the given supply and demand (which is recorded in and identified by blockchain) as the smart contracts negotiate the best price[23] and take care of the settlement and payment for the energy supply (8.2.2.), thereby enabling trust among the involved actors due to the removal of an intermediary (Wang et al., 2017; Andoni et al., 2019; Thomas et al, 2017; Mengelkamp et al., 2018a). Additionally, blockchain-enabled smart contracts reduce the decreased energy costs within microgrids even more, thereby incentivizing customer engagement even more (Andoni et al., 2019). This allows increasing power of consumers,

[22] Albrecht et al. (2018) were there first academic scholars to investigate the relationship between blockchain application and different areas within the energy sector, i.a. microgrids.

[23] Blockchain can consider price preferences and personal preferences such as from whom to buy and sell energy (Andoni et al., 2019).

hence incentivizing utilities to secure their market power[24] (Albrecht et al., 2018), especially since blockchain will most likely reduce the role of utilities and retailers (Brilliantova & Thurner, 2018). As a result, utilities might even need to innovate their business model to stay relevant within the microgrids, which can be achieved through a potential support function for customers, which would be based on their professional know-how (Mengelkamp et al., 2018a; Donnerer & Lacassagne, 2018).

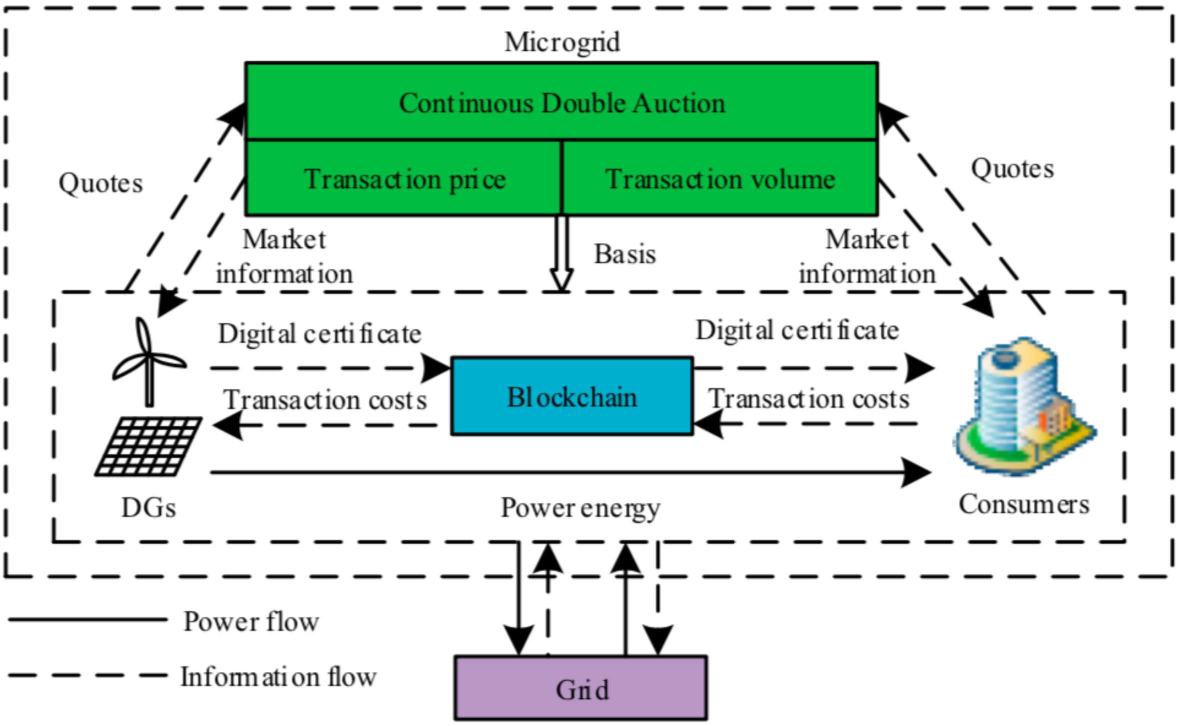

Figure 7: Overall structure of microgrid electricity transactions with blockchain (Wang et al., 2017; p.7)

Nevertheless, Andoni et al. (2019) indicate the importance of utilities[25] when implementing blockchain in microgrids as they own the physical infrastructure of the grid. That grid infrastructure is most likely to be used within the microgrid as otherwise the community would need to build its own grid and therefore would be disconnected from the main grid, which could cause problems when not enough electricity from RES generators is generated at a specific

[24] This can be done by changing their range of offerings. "Customer-friendly products like smart home applications may be offered to influence switching costs, tighten path dependencies and thus prevent the realization of network effects" (Albrecht et al., 2018; p.3533).

[25] In this case, it is referred to specifically to Transmission and Distribution system operators who are for the purpose of this study included in the encompassing term utilities. (Andoni et al., 2019)

time. Utilities[26] can use blockchain to precisely report the usage of their network, thus enabling exact network fee collection[27] based on individual energy transactions. Additionally, the capacity and power flows on their networks can be better managed as they will have the needed information about P2P transactions recorded on the blockchain[28] (Andoni et al., 2019).

Challenges

Even though the application of blockchain in microgrids seems very promising, especially regarding the ability to incorporate more RES generators in the grid, there are still challenges, which lead to the fact that this solution is not widely adopted yet. Zhaoyang et al. (2018) see the actual integration of blockchain and the energy physical infrastructure as problematic.[29] Blockchain as a solution for microgrids needs to be further improved from the technical perspective (Andoni et al., 2019). Moreover, the blockchain technology is competing with existing solutions[30] and needs to prove its profitability[31] to be implemented (Burger et al., 2016). Therefore, the scalability[32] and robustness of microgrids with blockchain need to be clearly identified (Mengelkamp et al., 2018a). Regulatory barriers are another major challenge that need to be overcome (Pöyry, 2017), such as not allowing P2P trading in many countries (Mengelkamp et al, 2018a; Burger et al., 2016). However, topics related to digitalization are already discussed by regulators in the EU (Pöyry, 2017). Nevertheless, BRET still has the potential to change the energy sector radically (Schwarz et al., 2018).

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[26] In this case, it is referred to specifically to Transmission and Distribution system operators who are for the purpose of this study included in the encompassing term utilities.

[27] Network fees will be relevant when using the public grid even though it is a local market place, thus affecting the tariff and prices set in P2P transactions (Andoni et al., 2019).

[28] These new ways of managing the network need further research (Andoni et al., 2019).

[29] The opportunity to trade energy leads to change of allocation of energy, leading to energy congestion and overloading and voltage deviation due to changed energy flow in the grid. Therefore, a system for the coordination of cyber and physical energy is needed (Zhaoyang et al., 2018).

[30] Therefore, it is easier for blockchain to be applied in systems without alternatives, which are usually developing countries (Burger et al., 2016).

[31] This means that the positive impact of applying blockchain in terms of securing energy supply and data need to be greater than the costs of establishing and maintaining this solution (Burger et al., 2016).

[32] A potential way to increase the scalability of microgrids is to connect several microgrids with each other, while enabling a hierarchy of grids, in order to have a widespread balanced demand and supply (C. Naucler, personal communication, March 15, 2019).

2.3.3. Use cases

A use case with blockchain application means that the actual application is tested in the real world, while demonstrating a certain scenario. Many of those use cases already exist worldwide,[33] especially in the financial sector. Parallel to that, the energy sector continues to expand with more use cases with a variety of different applications (Andoni et al., 2019; Dick & Praktiknjo, 2019). Different types of use cases can be analyzed through white papers, theoretical proof of concepts, simulations and pilot projects. Most energy blockchain projects are at an experimentation or pilot stage and have not been implemented in large-scale projects (Donnerer & Lacassagne, 2018).

Use cases in the energy sector

Many different research initiatives within the energy sector investigate the application of blockchain in use cases regarding (1) metering, billing and security, (2) cryptocurrencies, tokens and investment, (3) decentralized energy trading, (4) green certificates and carbon trading, (5) grid management, (6) IoT, smart devices, automation and asset management, and (7) electric e-mobility[34] (Andoni et al., 2019). Decentralized energy trading can be more specifically divided into (a) wholesale energy trading,[35] (b) energy trading support for small generators and end-consumers, (c) blockchain trading for utilities and energy systems stakeholders, (d) P2P trading in community projects and microgrids (Andoni et al., 2019). As this study is focusing on BRET, the other use cases will not be further discussed.

[33] One of the most popular use cases in the supply chain is explored by IBM and Maersk. They demonstrate the beneficial application of blockchain to digitize the paper-based processes within global trading in order to reduce transportation costs, inefficiency and lack of visibility (White, 2018).

[34] One famous blockchain use cases is a Share&Charge platform to facilitate the charging of EVs e.g. via payment (Andoni et al., 2019).

[35] One use case with potential is called Enerchain, which allows an enhanced and smart energy trading among regional markets. A consortium is developing this P2P wholesale energy trading platform, which is led by the IT service provider Ponton (Andoni et al., 2019).

Use case: microgrid

Several microgrids are being tested with the application of blockchain. Mostly startups such as LO3 Energy[36] or PowerLedger[37] are leading pilot projects like BRET. One of the most popular microgrids is the Brooklyn Microgrid[38] by LO3 Energy, which has grown a lot since 2016 and leads as the example of the application of blockchain in the energy sector. Since it is the first microgrid applying blockchain, some scholars have already made preliminary analyses of it. However, they all concluded that the "findings need to be further investigated to evaluate the economic and socio-economic impact of microgrid energy markets on their participants and the entire energy supply system" (Mengelkamp, 2018a; p.879).

Carson et al. (2018) have classified PowerLedger as an attacker[39] for penetrating the market when assessing its strategy used. Aiming to disrupt or even transform an existing market, demonstrates the severity of the role that startups like PowerLedger play. They suggest incumbents to deploy that strategy in a separate non-core digital business (Carson et al., 2018).

Next to pilot projects, other startups, such as Grid Singularity, are working on projects with simulations of BRET in microgrids, known as D3A.[40] Eventually, the D3A can support microgrid operators. Together with the Rocky Mountain Institute, they founded the consortium EWF,[41] which is developing its own blockchain "Energy Web" (EWF, n.d.a).

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[36] A US-based startup (hereinafter referred to as LO3) which "is developing blockchain based innovations to revolutionize how energy can be generated, stored, bought, sold and used, all at the local level" (LO3 Energy, 2018; para.1)

[37] An Australian startup that envisions the creation of a different kind of energy market and has built a series of blockchain-based products to get the world there, e.g. via microgrids (PowerLedger, 2019).

[38] It started in 2016, when piloting the application of blockchain in a P2P trading system. In the beginning 10 households were part of the decentralized electricity system, with 5 households being prosumer and 5 simply consumers. Including smart meters, smart contracts and blockchain, the prosumers trade their energy, that they did not need, directly to the the neighbors (Bundesministerium für Wirtschaft und Energie, 2017). One objective is to create a local renewable energy community (Donnerer & Lacassagne, 2018).

[39] Attackers aim to disrupt or transform existing systems. Therefore, that approach is appropriate for use cases with the highest disruptive potential by providing a service to the market that would disintermediate current players. This is applies for blockchain-enabled P2P applications (Carson et al., 2018).

[40] D3A stands for Decentralized Autonomous Area Agent (Grid Singularity, 2019)

[41] EWF is a consortium which consists of multiple energy incumbents, startups, technology providers and they are working on creating the Energy Web as a blockchain for P2P trading (EWF, n.d.b)

2.4. Research gap

The research of blockchain is a nascent field, especially when focusing on the energy sector and one specific application area. Andoni et al. (2019) claims that: “Additional research initiatives, trials, and collaborations will show if the technology can reach its full potential, prove its commercial viability and finally be adopted in the mainstream” (Andoni et al., 2019; p.167). We believe that in order to find out whether BRET can reach its full potential within the energy sector, it is necessary to understand (1) which stakeholders are relevant in the process of its advancement, (2) in what way those stakeholders are relevant, (3) what impact they will have when acting independently or with someone else. Even though many scholars focus on the technical aspects of blockchain within the energy sector, only few adopt the business perspective. Consequently, no academic research has explicitly addressed the identification of relevant stakeholders, their interactions and assessment of those interactions on advancement of blockchain technology in the energy sector.

Additionally, nearly all literature in this field is trying to offer an encompassing view rather than focusing on a specific use case, such as BRET. It is paramount to develop a comprehensive in-depth analysis to fully understand the potential based on what we derived as our research questions (1.1.).

2.5. Theoretical framework

When constructing the theoretical framework, which will be used for analyzing the empirical data relevant for filling the research gap, it is important to acknowledge that this study is looking at the advancement of BRET at an industry level and not on an individual company level. Therefore, it is not expedient to use a theoretical framework that is focusing on an individual company’s perspective of accepting blockchain as an innovative technology within the energy sector, such as the Technology Acceptance Model (TAM) by Davis (1989) (Albrecht et al., 2018). The advancement is dependent on multiple actors, their interdependence and various environmental and institutional factors. These are not emphasized to a sufficient extent in TAM (Albrecht et al., 2018). Thus, we concluded that TAM does not offer the needed perspective. It is crucial to acknowledge which actors are relevant when understanding the ongoing advancement of BRET. Understanding the relationships and interactions among all actors[42] is key to determine who, and to what extent, influences the advancement process. Therefore, mapping the business ecosystem according to Moore (1993) will add critical value in understanding the holistic picture of the current situation of advancement of BRET in the energy sector. Five types of ecosystems streams exist: business, ecosystem, innovation ecosystem, entrepreneurial and startup ecosystems, platform ecosystem and service ecosystem (Aarikka-Stenroos & Ritala, 2017). Following the identification of actors relevant for advancement of BRET (3.1.2.), we have considered business and innovation ecosystems. Their applicability is discussed as follows.

As stated in the background, there are multiple actors from different backgrounds that are investigating blockchain as an innovative application within BRET. However, their relationships have not been analyzed yet. According to Moore (1993) and Li (2009), companies in a business ecosystem co-evolve competencies around a new innovation, which relies on competition and cooperation. Co-evolution refers to “the complex interplay between competitive and cooperative business strategies” (Moore, 1993; p.76). Such business ecosystems constitute a network that is interconnected, cooperative, but still competitive, while emphasizing collaboration and supply-chain aspects (Iansiti & Levien, 2004; Adner, 2017). Within an ecosystem, interdependencies are created, which can be due to several factors such as shared purpose, shared intentions, affiliation, or a technological platform providing connectivity (Aarikka-Stenroos & Ritala, 2017). A business ecosystem consists of value network actors (hereinafter referred to as actors), related technologies and institutions (figure 8) (Aarikka-Stenroos & Ritala, 2017). Actors are “the end-users or customers and user communities, developers and research organizations, competitors, and complementors throughout the entire value chain and network [...], as well as institutional actors” (Aarikka-Stenroos & Ritala, 2017; p.24). While technologies are defined as “various types of platforms and technological frameworks that are shared by the ecosystem actors.” (Aarikka-Stenroos & Ritala, 2017; p.24). For the purpose of this study and in order to reflect on the ecosystem framework, we have adopted the term regulations instead of institutions. Regulations are referred to as a set of policies, laws and industry-specific rules designed by institutional actors to regulate behavior. Hence, we distinguish institutional actors from institutions as acting

[42] Who were identified in the pre-study (section 3.1.2.): incumbents, startups, institutional actors, consultancies, technology providers, other experts.

participants of the ecosystem who engage with other actors, participate in events and design the regulations.

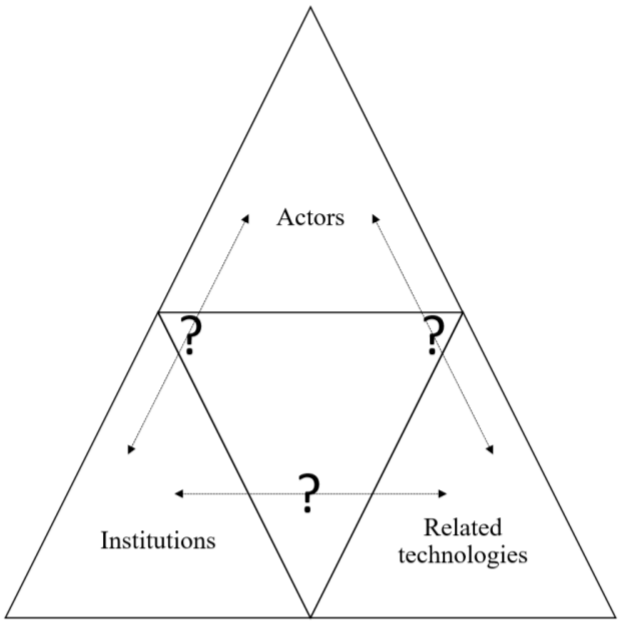

Figure 8: Ecosystem Framework (based on Aarikka-Stenroos & Ritala, 2017)

Another identified type of ecosystem besides the business ecosystem is the innovation ecosystem, however that focuses on firm-centric innovation and does not put enough emphasis on the interactions of different actors (Aarikka-Stenroos & Ritala, 2017). Since BRET represents a network-centric innovation, the focus on actors is paramount to analyze its advancement. Therefore, the business ecosystem was chosen as more appropriate for the purpose of this study. Generally, the ecosystems approach is increasingly used by scholars to analyze the interdependencies in business networks and co-evolutions of business and innovation activities (Aarikka-Stenroos & Ritala, 2017).

Moreover, it is also relevant to identify the current evolutionary stage of the business ecosystem in order for one actor to know how to deal with the innovation to maintain or gain leadership (Moore, 1993). Moore (1993) has classified the development of the business ecosystem into four stages (figure 9). All stages have specific leadership, cooperative and competitive challenges (table 1). The boundaries between the stages usually blend, hence these kinds of challenges from different stages might occur simultaneously (Moore, 1993). It is important that a leader emerges during the first stage “to initiate a process of rapid, ongoing improvement that draws the entire community toward a grander future” (Moore, 1993; p.79).

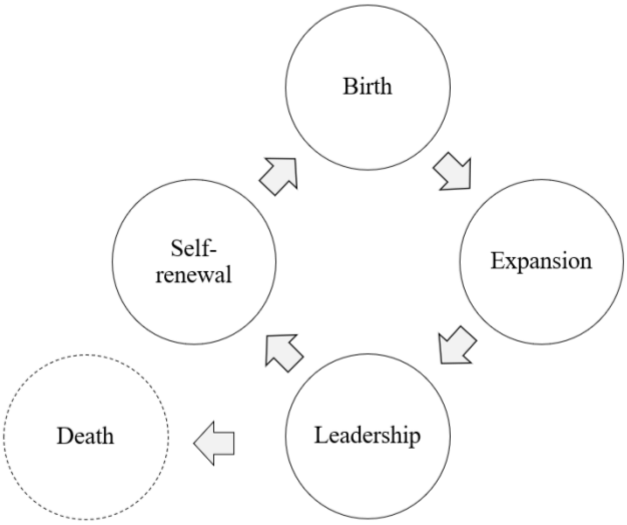

Figure 9: Stages of the Business Ecosystem (based on Moore, 1993)

Stage	Overall leadership challenges	Cooperative Challenges	Competitive Challenges
Birth	Value	Work with customers and suppliers to define the new value proposition and a paradigm for providing something that is dramatically more effective than what is available.	Protect your ideas from others who might be working toward defining similar offers.
Expansion	Critical mass	Bring the new offer to a large market by working with suppliers and partners to scale up supply and to achieve maximum market coverage and critical mass.	Defeat alternative implementations of similar ideas. Ensure that your approach is the market standard in its class through dominating key market segments. Tie up critical lead customers, key suppliers, and important channels.
Leadership	Lead co-evolution	Provide a compelling vision for the future that encourages suppliers and customers to work together to continue to improve the ecosystem.	Maintain strong bargaining power in relation to other players in the ecosystem, including key customers and valued suppliers.
Self-Renewal	Continuous performance improvement	Work with innovators to bring new ideas to the existing ecosystem.	Maintain high barriers to entry to prevent innovators from building alternative ecosystems. Maintain high customer switching costs in order to buy time to incorporate new ideas into your own products and services.

Table 1: Challenges of the evolutionary stages of the business ecosystem (Moore, 1996; p.83)

While the existing ecosystem depicts the relevant interactions among actors, it is important to analyze the individual actors, their capabilities and perception of BRET. This analysis will enable us to assess the actors' individual potential impact, especially in combination with another actor. This assessment will allow us to uncover factors that facilitate or hinder the advancement of BRET. This is due to the fact that such factors demonstrate what is holding the individual actors back from implementing that solution, but also who is potentially driving the advancement. Therefore, the necessary criteria for a potential implementation of BRET will also be analyzed. The innovation-decision process by Rogers (1983) facilitates that analysis of the individual actors, showing in which innovation-decision stage they are in and demonstrating that the decision to accept or reject BRET is a process instead of one specific act.[43]

According to Rogers (1983), the five sequential stages of the innovation-decision process are knowledge, persuasion, decision, implementation and confirmation (figure 10). The first stage of knowledge means that the individual is introduced to the innovation's existence, gains an understanding of how it works. In the second stage, persuasion, the individual forms an opinion about the innovation. Individuals do not necessarily pass the persuasion stage as they sometimes neglect it and move from the knowledge stage directly to the decision stage. When being in the decision stage, the individual is actively engaging in activities that will be followed by a choice of either adopting or rejecting the innovation. Sometimes, the second and third stage can interchange and the decision occurs before persuasion, which is rare. In the implementation phase, the individual actor employs the innovation to a varying degree depending on given circumstances. In the final stage, confirmation, the individual reinforces the decision made and might potentially adjust the innovation for increasing the probability of acceptance by consumers (Rogers, 1983).

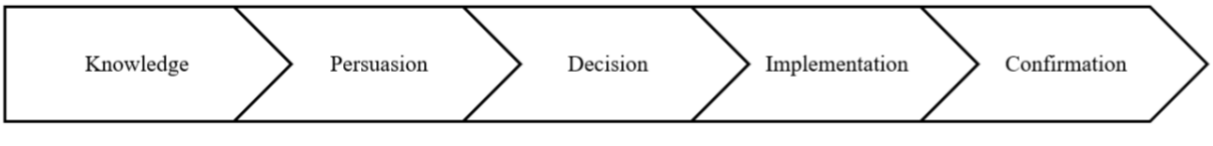

Figure 10: innovation-decision stages by Rogers (1983)

[43] It is important to note that only the stage of the actor within the innovation-decision process will be analyzed and not how decisions are actually made.

The combination of the ecosystem and the innovation-decision stages will serve as a framework that allows to identify how relevant actors in the innovation process interact, what the impact of those interactions is and what is needed to advance BRET.

3. Methodology

In this section, the chosen scientific research and methodological approach will be described and explained to demonstrate why that approach is the most appropriate for our identified research questions. First, we introduce our pre-study, which is followed by the main study. Second, we will outline our abductive research approach and present our choice of qualitative exploratory-explanatory case study. Thereafter, we describe the chosen methods, which is followed by a discussion of the quality of research.

3.1. Pre-study

3.1.1. Initial focus

As both authors were interested in new technologies and innovation in the energy sector, the topic of this study was chosen to be close to both. Therefore, we decided to focus on the energy sector and to determine which innovative technology is the one that has the potential to disrupt the market. Hence, we chose to analyze the application of blockchain within the energy sector.

First, we were interested if and how blockchain is being diffused in the energy sector and on what technical factors it depends. Second, we wanted to understand who the relevant actors are and what their role is. Third, we were interested in the dynamics within the sector and comprehending the current challenges of the sector.

Hence, we conducted an extensive literature review on the application of blockchain in the energy sector which was complemented by literature concerning the technology itself to gain a thorough understanding of the technological design and blockchain application in other markets[44].

Nevertheless, it was necessary to narrow down our research focus due to: (1) the variety of use cases, and (2) our ambition to choose a phenomenon which would allow us to create valuable knowledge relevant for advancing blockchain (2.4.).

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[44] FinTech, RegTech, LegalTech, InsurTech, supply chain, food safety, healthcare.

3.1.2. Pre-study data collection and analysis

The pre-study consisted of four interviews with blockchain experts from academia and consultancies (8.3.) and two observations in two workshops on blockchain (8.4.). The goal of the pre-study was to gain an understanding of the blockchain potential in the energy sector, with an additional focus on determining which use cases are perceived as the ones with the largest interest to be further investigated due to the relevance for academia and market. Moreover, becoming acquainted with the technical aspects of blockchain was fundamental to be able to critically assess its advantages over the legacy and other alternative systems and technologies.

Based on these goals, the interview questions evolved around the interview participants' experience with blockchain and energy, functionalities and design of blockchain, opinion on existing use cases and future development of blockchain in energy sector.

When learning how to build blockchain apps during the first workshop, our technical understanding of blockchain technology was enhanced. The other observation at the workshop at IBM provided us with a good understanding of Hyperledger (the IBM blockchain platform) and its practical use and value.

The pre-study findings made us redirect our focus from the blockchain technology maturity in the energy sector to the role of the actors (table 2) and relationships among them. Moreover, it allowed us to identify the most suitable use case for our purposes, BRET. This made us pivot from our initial intention to focus on technology acceptance and diffusion theories to adapting a lens of the ecosystem approach (Moore, 1993; Moore, 1996).

Actor	Role summary
Incumbents	Generate, distribute, retail electricity and provide the electricity infrastructure and services to their customers
Startups	Their core business activities evolve around BRET as they want to democratize and decarbonize the energy market
Consultancies and technology providers	Develop blockchain platform and technology, have experience with BRET
Institutional actors	Design a set of policies, laws and industry-specific rules to regulate behavior relevant for BRET and its advancement

Table 2: Relevant actors and their role

There are more actors that interact with the business ecosystem of BRET (BRET ecosystem). Nevertheless, their position has been assessed at the limits or outside of that ecosystem, which is usual because ecosystems are identified as open systems with blurry boundaries (Aarikka-Stenroos & Ritala, 2017).

3.2. Methodological fit

3.2.1. Abductive approach

While Arbnor & Bjerke (2009) state that "induction starts from facts and deduction from theory" (p.92), our study adopts a combination of both. Moving between induction and deduction allowed us to pursue iterative knowledge creation drawing simultaneously on theory and empirics. This is particularly suitable for nascent research topics (Dubois & Gadde, 2002) such as the phenomenon of this study. We have started with a focus on Technology Acceptance and Diffusion Theories while remaining open for input from the interviews and observations. After each interview, we reviewed our theoretical lens, re-defined it, and then re-formulated the interview guide, i.e. the questions being asked shifted to focus on actors and relationships among them.

With the accumulation of empirical knowledge, we have constantly redirected the focus of our interviews. This made us pivot in the work with existing theories and ultimately led us to select Moore's (1993) ecosystem approach and subsequently the innovation-decision process to guide us in identifying the nature of rationale behind relationships within the ecosystem. Hence, we concurrently explored theory and the context of blockchain and energy sector, i.e. moving between induction and deduction.

3.2.2. Ontology and epistemology

We took a constructionist ontological stance since we consider the reality to be shaped through constant interrelations and interactions of social actors (Bryman & Bell, 2015). This is in line with analyzing the business ecosystem as a dynamic network of mutually interconnected actors who constitute the phenomenon at the center of our study (Maggetti et al., 2013). Our epistemological position is interpretivist since we strive to understand the social world "through an examination of the interpretation of that world by its participants" (Bryman & Bell, 2015).

3.2.3. Qualitative approach

To answer the research questions (1.1.), a qualitative research approach was deemed most suitable. It corresponds to our ambition to contribute to the nascent field of research where "detailed, and evocative data are needed to shed light on the phenomenon" (Edmondson & McManus, 2007; p.1162). Furthermore, no specific hypothesis was introduced at the outset of the study (Silverman, 1993).

3.2.4. Single-case study

More specifically, this study is designed as a case study. We follow the qualitative case study definition of Barratt et al. (2011): "an empirical research that primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon" (p.329). Hence, the case study method was chosen to allow for in-depth exploration of the phenomenon of advancing BRET and thereupon demonstrate its relevance (Benbasat et al., 1987). The setting of the context is bounded to prevent us to "attempt to answer a question that is too broad or a topic that has too many objectives for one study" (Baxter & Jack, 2008; p.546). Hence, we bind the setting of the case to the European context due to the specificity of the technological, regulatory and competitive landscape.

This study uses a single case as it enables to develop in-depth knowledge in the chosen research questions. We are aware of the trade-off with a single case study concerning limited generalizability (Yin, 2009), but we do not consider this as an issue due to the nature of our study and the contribution to a nascent academic area of research as well as the unarguable specificity of the blockchain technology. Furthermore, "Levy (1988) established the single-case explanatory-exploratory methodology as the most suitable choice for the investigation of information technology" (Tellis, 1997; p.9) which further supports this methodological choice since blockchain is an information technology.

The goal of this study is to examine the phenomenon of advancing BRET. As demonstrated in this study's background section, this is a novel academic research area[45] that has only recently started to be explored (Andoni et al., 2019). Moreover, the phenomenon has no certain set of outcomes yet, which validates the use of the exploratory approach (Yin, 2003). Nevertheless, Yin (2003) highlights that "the boundaries between the strategies are [not] always clear and sharp" (p.4). Hence, alongside exploratory, we have an explanatory research purpose which allows us to offer an in-depth analysis of causal relationships and answers not only "what" questions but also "why" and "how' questions, which are usually explanatory (Yin, 2003).

Hence, this study adopts both exploratory and explanatory research strategies.

3.3. Methods: collection and analysis techniques

3.3.1. Data collection

Interviews

The primary research method of our data collection were semi-structured individual interviews. This choice was motivated by our intention to understand the participants' attitudes, perspectives and opinions as well as drawing on their experience and knowledge of BRET.

Each interview followed an interview guide (8.5.) which was re-formulated prior to each interview, building on the already collected data and literature. Every interview guide included main themes, a focused structure and was subject to change depending on the duration of the interview (Kallio et al., 2016).

The format of semi-structured interviews which requires "openness, flexibility and improvisation" (Myers & Newman, 2007; p.14) allowed us to ask questions outside of the frame of the interview guide. This steered the questions around the specific expertise of the

[45] Meaning a topic that has not been researched on to a greater extent (Blomkvist & Hallin, 2015)

particular participants and the emergent topics. On many occasions, this led to discovery of “unknown unknowns” (Mullins, 2007) which, in line with our abductive approach, enabled us to steer the course of our research and direct our focus. Furthermore, it allowed us to evaluate the degree of importance that the participants attributed to particular factors and ideas.

Sampling

To collect adequate data, the sampling of interview participants was purposive. The accumulated knowledge during our pre-study led us to identify four actors who we determined to be key in including in our sample. Then, we aimed for a variety of organizations within those groups in identifying specific individuals who have experience with blockchain-enabled solutions. We complemented this sample with experts in the field from academia and other organizations.

Following Schreier’s (2018) three criteria distinguishing among types of purposive sampling, the characteristic of our study are the following: (1) the sample’s composition was determined over the course of the study (2) our sample is heterogeneous to represent a maximum variation in viewpoints (3) the participants were selected with regard to representativeness as we aimed to select “typical” representatives of companies which however was challenging since only a limited number of individuals have experience with blockchain-enabled solutions (Schreier, 2018).

Furthermore, the purposive sample size “typically relies on the concept of ‘saturation’” (Guest et al., 2006; p.59) and in addition to groups of actors, which were identified upfront, the snowballing technique was applied as interviewees were asked who they would recommend us to interview next.

It should also be noted that although we interviewed the representatives of organizations, we acknowledge that they have their own understanding of the world, motivations, biases and specific knowledge or understanding stemming from their personal experience as well as the part of the organization they work in. Hence, it is important to accentuate that the opinions and statements included in this study might not be representing the official stance of the interviewees' organizations.

In total, we have conducted 22 interviews (in addition to four in the pre-study) (8.6.). As illustrated in figure 11 below, the participants belonged to either one of the four groups of actors (represented by hexagons) or were blockchain experts from outside of the ecosystem.

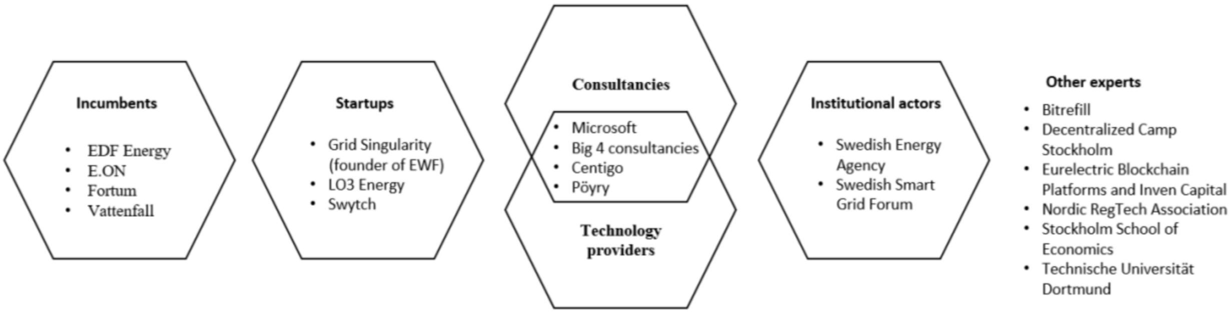

Figure 11: Overview of the organizations, members of which were interviewed in the pre-study and main study

Interview process

The interviews were conducted either via phone or in person. The latter was preferred since they provided richer source of information (Brinkmann, 2013), however a number of interviews was conducted via phone due to the geographical distance or preference of the participant. Nevertheless, contrary to Roulston & Choi (2018), it was not observed that the phone interviews would generate "less descriptive accounts" (p.245). This might be due to the non-sensitive nature of the discussed topics.

We prepared before each interview by familiarizing ourselves with the background and experience of the participants as well as their organizations. This enabled us to adapt the interview guides accordingly, fully making use of the interview time and facilitating the establishment of trust of the participants and us (Roulston & Choi, 2018).

We have started every interview by informing the participant of our personal background, the purpose of our research and the current stage of it. We then asked the interviewee whether we can record the interview and come back to them in case we decide to use their direct quotes. The first question was always "What is your background in energy and blockchain?" The structure of each interview either followed the main themes formulated in the interview guide or was adapted based on the participant's input. Since we were two interviewers, one was in charge of leading the interview, the other one was taking extensive notes.

Observation

One author participated in the conference "The future of electricity markets in a low carbon economy" on April 2nd, 2019 organized by the Swedish Smart Grid Forum and acted like a witness instead of interviewer or listener, which is typical for observations (Wästerfors, 2018). During that conference, startups, incumbents, consultancies and institutional actors participated, thereby representing the identified relevant actors of the ecosystem (table 2). As identified in the research gap (2.4.), the authors were convinced that interactions among these actors existed and were relevant to be observed in the context of BRET (Wästerfors, 2018). The author tried to discover the social and interactional processes and listened carefully to conversations among other participants. Following the ethnographic guidelines of Wästerfors (2018), the author was able to view knowledge exchanges among actors and other interactions.

Secondary data

In addition to the primary data that was collected through interviews and observations, we collected extensive secondary data. The purpose of this data collection was to complement as well as triangulate data whenever it was applicable. This was particularly useful when participants referred to the vision of their organizations, their accomplishments and specific events.

The following types of secondary data were used: (1) white papers, e.g. D3A synopsis, (2) industry reports drawn up by consultancies, (3) annual reports of utility companies, (4) public institutions reports, (5) academic articles, and (6) internet articles.

3.3.2. Data analysis

By coding, we aimed to create linkages between data by moving from data to idea, which will in turn lead us to all the data that refer or provide the foundation for the identified idea (Richards & Morse, 2007). This allows us to identify patterns such as similarities, differences, correspondences and causations (Hatch, 2002). The coding process "generates the bones of [our] analysis [and the] integration will assemble those bones into a working skeleton" (Charmaz 2006; p.45). For us, "coding is only the initial step toward an even more rigorous and evocative analysis and interpretation for a report" (Saldana, 2013; p.8).

The coding process was preceded by pre-coding (Saldana, 2013) which consisted in underlying passages of the transcribed text that we deemed relevant. This process also served as a foundation to refine the coding scheme which was constructed based on: (1) the research questions (1.1.), and (2) the information accumulated throughout the data collection process. Based on this, we formulated codes falling into nine categories. “Coding distills data, sorts them, and gives us a handle for making comparisons with other segments of data” (Charmaz, 2006; p.3).

Following Campbell et al. (2013), we structured the coding process in three stages. First, a randomly selected sample of one transcript was independently coded by both authors in order to assure intercoder reliability (Campbell et al., 2013). This was followed by a discussion aiming to define the specific codes more precisely and assuring the fit to our theoretical framework. This led to merging two categories and reducing the number of codes to make the coding scheme simpler to "improve intercoder reliability and agreement, save time, and avoid codes that may turn out later not to be useful" (Campbell et al., 2013; p.308). In a second stage, another randomly selected transcript was coded by both authors. The intercoder reliability was assessed as fairly high, which was contributed to by the same level of knowledge of both coders. Thereafter, the structure and content of the coding scheme were agreed upon. The third stage consisted of deploying the coding scheme (8.7.) on all the transcripts by one author, ‘the knowledgeable single coder’ (Campbell et al., 2013). Subsequently, the total of 752 quotes were moved to an Excel sheet following the coding scheme structure.

This Excel sheet was then used throughout the analysis as it was a valuable tool in identifying second order constructs (which are articulated as headings of subsections 4.1., 4.2., 4.3., 4.4. and 4.5.) and formulating the empirical findings in a comprehensive way (4.). The most accurate quotes underpinning the findings were placed in the appendix (8.8.). When applying the theoretical framework on our data, the codes guided us to an in-depth analysis. E.g. the construct of “motivation and attitude of incumbents towards blockchain” allowed us to assess their innovation-decision stage, while the “interaction between market actors” allowed us to analyze the interactions in the ecosystem. Such methodological approach enabled creating a bridge between the theoretical concepts and empirical data.

Before discussing the quality of this study, we would like to give an overview of the research process (figure 12).

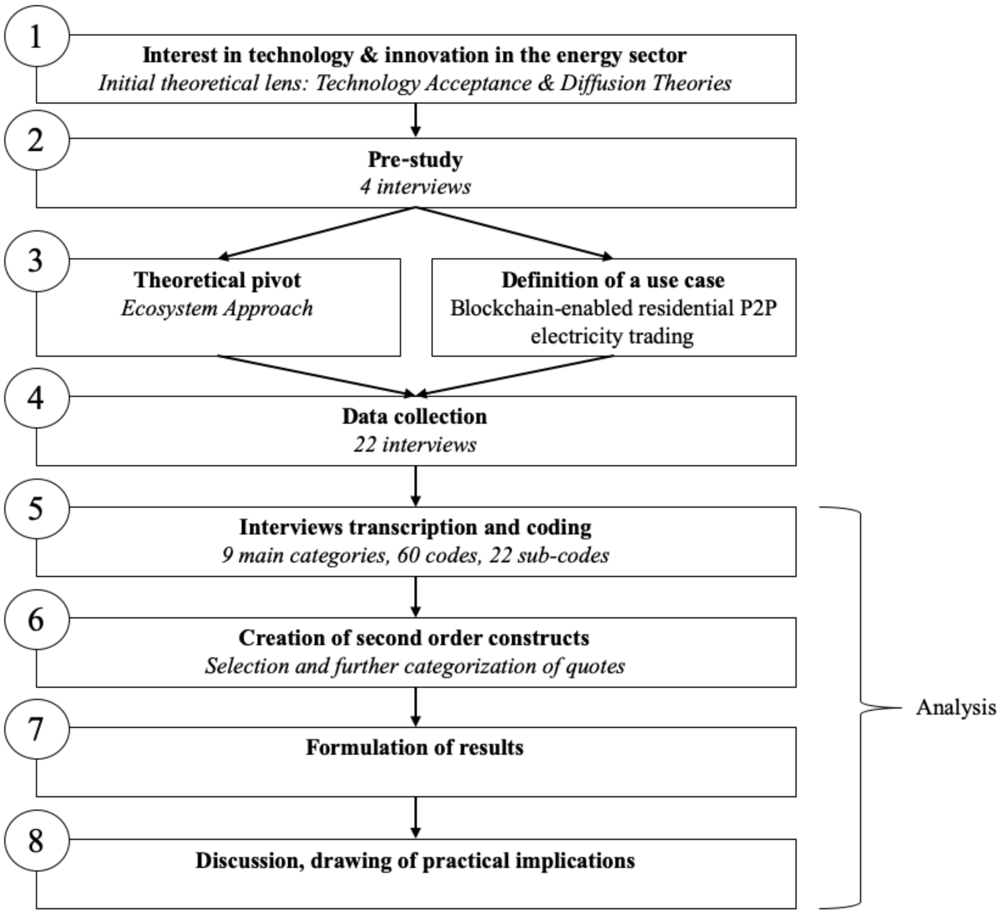

Figure 12: Overview of the research process

3.4. Quality of study

In this subsection, we elaborate on the methodological trade-offs made with the choice of the research design. Based on Yin (2003), the quality of this case study design is discussed alongside construct, internal and external validity, and reliability (Yin, 2003).

3.4.1. Validity

Qualitative research refers to validity as "the extent to which an account accurately represents the social phenomena to which it refers" (Hammersley, 1990; p.57). Hence, multiple techniques were employed to "eliminate obvious mistakes and to generate a richer set of explanations of [our] data" (Gibbs, 2007; p.93).

Construct validity

Triangulation

We drew on multiple sources of evidence to assure convergence of data. Even though we are constructivists and agree that "each piece of research will offer its own interpretation of what it finds" (Gibbs, 2007; p.94), we still try to achieve a certain level of objectivism across those perspectives while avoiding errors in their interpretation. Further review and validation of data was assessed as not necessary since the triangulation stemming from multiple sources of data allowed for validation of the data-to-be-analyzed.

Pattern-matching

Following Shraga & Shirom (2009), the coding was an iterative process of identifying repeating patterns and matching the data to refine the final coding scheme. Pattern-matching was conducted with rigor to ensure that all relevant information from the interview transcripts was identified and placed in respective coding scheme categories and codes. Coding scheme was iteratively created by re-editing the scheme while reading the transcripts and complemented by the thorough knowledge of the content of the transcripts by both authors.

Internal validity

Internal validity is a relevant quality criterion for explanatory-exploratory case study such as this one. It tests "the correctness of our conclusion of a relationship" (Meredith, 1998; p.447). To ensure internal validity, precautions to prevent inference by the authors in the data collection and analysis were taken (Yin, 2003). First, the analysis of the results was done individually and then compared to identify potential bias of the authors. Second, a broad sample of interview participants from different group of actors, organizations and functional areas was chosen to limit bias (Eisenhardt & Graebner, 2007). This ultimately led to adequate engagement in data collection (saturation).

External validity

The external validity of our findings is limited as the purpose of this study is to shed light on a new technology which has not been extensively studied before. Due to this novelty, it is difficult to say how generalizable the findings of this study will be in the future when the technology employed in BRET matures. Nevertheless, it might be possible that our findings will become generalizable for other new technologies that might emerge in the future to understand and foster their advancement. However, as it is uncertain how and if the technology matures, we do not aim to generalize at this point in time.

3.4.2. Reliability

In qualitative research, reliability is defined as "the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions" (Hammersley, 2013; p.67). Hence, the goal was to "minimize the errors and biases in [our] study" (Yin, 2003; p.36). Main instruments that contributed to that goal were proper documentation of conducted procedures and cooperation in teams of two which allowed for constant checking and comparing (Gibbs, 2007).

To ensure reliability, we transcribed all interviews from the main study and documented those in addition to the original recordings and extensive notes from the interviews. Each author manually transcribed 11 interviews (of the total 22 main study interviews). Those transcripts were then reviewed by the other author while listening to the recording to reduce the possibility of mistakes.

The coding scheme was developed at three stages: (1) formulating a preliminary coding scheme, (2) coding one randomly selected interview by both authors, comparing the results and refining the scheme accordingly, (3) finalizing the coding scheme with appropriate definitions which were agreed upon by both authors.

Reliability during the coding was ensured by the fact that one author coded all the interviews while the other author moved the quotes to the Excel sheet. In case of any disagreements, specific issues were discussed. This ultimately ensured a high intercoder reliability. Emphasis was put on the concepts behind the code while acknowledging that it is "often rather arbitrary where coding starts and finishes" (Gibbs, 2007; p.100). Moreover, focus was put on avoiding a definitional drift' and other types of inconsistencies (Gibbs, 2007). While one author was responsible for selecting and structuring the quotes in the empirical findings' tables (8.8.), the other author continuously reviewed the content and discussed when necessary to ensure that the data fit in the agreed categories and theoretical framework.

All interviews were conducted in English except one, in German. This interview was fully translated by one author before coding. The motivation of this was to ensure that all interviews were coded under the same conditions and the connections between the coding scheme and transcripts made in the identical way.

3.4.3. Ethical considerations

Throughout the research process, we were guided by ethical considerations. Even though the interview content is not to be considered sensitive, we made precautions to treat it in the confidential way. This was particularly important since we decided to disclose the names of the participants with their prior approval. Accordingly, all participants were asked (1) for permission to record the interview and (2) in case we decide to include their direct quotes, to contact them to gain consent that we can publish the quotes in such form and with their names. Only one interviewee asked to be anonymized. Hence, after selecting the quotes (8.8.), relevant participants were contacted by email to obtain their approval, explicitly stating the context in which the quotes would be used and that their names and organizations would be disclosed alongside those quotes. Subsequently, some quotes were marginally adjusted and several excluded.

4. Empirical Findings

This section presents the empirical findings of the study, divided in five sections. First, it is examined what leads actors to decide to pursue BRET activities. Second, factors why actors do not pursue those activities to a greater extent are presented. Third, it is demonstrated that those impeding factors can be overcome through cooperation. Lastly, the nature of these interactions is examined.

4.1 Actors' motivations to participate in BRET activities[46]

Interview participants explained why various group of actors engage in BRET activities.

4.1.1. Incumbents

It was found that the incumbents participate in BRET activities because: (1) there is an uncertainty what it means for their business, (2) they want to stay up-to-date with the development within the energy sector, (3) develop new competencies to be prepared if blockchain be adopted in the mainstream. Those can be summarized in two underlying motivations. First, to stay relevant, as highlighted in the following quote:

> *"I think the energy companies [...] should look in this kind of things to stay relevant and pursue further investigations, try out things and so on, to have that ready when blockchain will be even more mature and well established."*- Martin Knaack, Microsoft

The second underlying motivation is to identify how BRET could add value to the incumbents. The value can be created either through: (a) automated operations by making them faster and disintermediated, i.e. reducing use of third parties; (b) offering new services and improving interactions with clients.

[46] See 8.8.1. for an extensive list of quotes

4.1.2. Startups

Startups are motivated to pursue BRET mostly by two objectives. First, they want to democratize the electricity market by empowering more players, as illustrated here:

> *"We are trying to democratize the electricity market, so that everybody could be a participant, especially the prosumers and consumers at the distribution level"*- Fatuma Mohamed, Grid Singularity

This would enable shared economy practices such as selling energy among neighbors without a third-party involvement.

Their second aspiration is to reduce CO2 emissions as the BRET schemes would incentivize more consumers to become prosumers, i.e. it would become more financially attractive to invest in PV panels, and in turn increase the renewable energy consumption. Furthermore, as several participants highlighted, BRET would make the electricity market more efficient by reducing electricity losses as: (1) the distance between energy generation and consumption would dramatically decrease, and (2) the blockchain technology could improve the balancing of electricity supply and demand. With less electricity lost, the CO2 emissions could significantly decrease.

4.1.3. Consultancies and technology providers

Consultancies and technology providers choose to engage in BRET activities as they want to stay up-to-date with the technology to be able to provide services to the incumbents.

> *"I do not think that there are players with the capabilities that we have, so definitely there is some investment"*- Martin Knaack, Microsoft

The above quote depicts that they want to combine their unique set of capabilities and experience with knowledge of blockchain application in the energy sector. Moreover, they want to accumulate experience in blockchain-specific area and increase their own know-how to improve their competencies in advising and assisting in the implementation of blockchain-enabled solutions such as BRET.

4.1.4. Institutional actors

It was found that the institutional actors are active in observing the ongoing BRET activities to learn how the technology could work in practice and what the direct and indirect implications for the customers and the society overall are.

> *"There needs to be an update to the regulations on what is permitted of what is allowed"*- Richard Rosenholtz, Nordic RegTech Association

This quote draws attention to the importance of institutional actors to follow the development on the market in order to be able to revise the regulations at the speed of the technology's development to prevent legal "grey zones" to emerge, which also represents a motivational aspect of the institutional actors to participate.

4.2. Impeding factors preventing BRET activities to be pursued to a greater extent[47]

4.2.1. Inflated non-specific expectations

The majority of participants noted that there have been many inflated expectations around blockchain which caused many individuals to consider it as an all-can-solve magic, which was discussed at a general level in connection with excessive number of issues. They accentuated that blockchain became a buzzword which distracted attention from specific problems which would have benefited from the actual functionalities of blockchain.

> *"We need to be more specific and speak about things which are not buzzwords but about things which are achievable, which are tangible"* - Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital

The above quote refers to the problematic nature of looking at blockchain as a fashionable technology.

4.2.2. Uncertainty about substitutability of blockchain functionalities

Some participants, particularly from the incumbents, revealed that they are not convinced whether another technology, such as their existing database system, would be able to fulfill the

[47] See 8.8.2. for an extensive list of quotes

same functionalities as blockchain for BRET. This uncertainty was highlighted by other participants who expressed that there must be clarity and agreement in which specific cases blockchain application is the best option available:

> *"Swedish power company to implement blockchain [...] what can they only do with the blockchain or what can they do better with a blockchain. And if you can answer that question, it is going to be a hype."*- Jonas Wallenius, Decentralized Camp Stockholm

4.2.3. Blockchain is an immature technology

All participants noted that they see the technology used in BRET as immature which prevents them to pursue BRET activities to a greater extent.

> *"One of the learnings, that what we did, the technology is quite immature"* - Catarina Naucler, Fortum

Despite BRET's unique value proposition, such as transparency, trust-lessness supporting the trade between neighbors via smart contracts, incumbents are either hesitant or reluctant to implement it as the technology itself still has many challenges to overcome. In contrast, startups perceive the technology's immaturity rather as a challenge which does not allow them to fulfill some of their objectives. Accordingly, they actively seek to overcome it.

4.2.4. No standardized technological design or platform

Another impeding factor referred to by most participants was that there is not one single technology design or platform enabling BRET which is recognized and used by a majority of relevant actors.

> *"I think you need to come up with standard [...] or systems that connect disparate systems together that speak the same or similar language [...] without that it is going to be very difficult"*- Evan Caron, Swytch

Hence, there are currently many alternative blockchain designs, none of them being the dominant one. Yet, there is a need to come up with one single platform standard that everyone would use which would allow for compatibility with existing and emerging systems. Two blockchain design features the participants were accentuated by multiple participants: consensus mechanism and a certain type of blockchain platform. They suggested that those should be agreed on to achieve compatibility with other systems and potentially allow for emergence a future standardized design. Regarding consensus mechanisms, proof-of-work is currently most commonly used, however, this is associated by participants as well as experts and academics with many disadvantages (2.2.1.), hence is widely believed to be abandoned in the future. The alternative consensus mechanism that most participants described as the most likely to be widely adopted in BRET is proof-of-authority. In regards to the type of blockchain platform, most participants believed that private or consortium platforms will prevail and become the basis for the future "single platform" standard.

Regarding the emergence of one platform that would be recognized and used by majority of stakeholders, it was confirmed throughout the interviews, that Hyperledger and Energy Web are the most probable ones (both being consortium blockchain platforms).

4.2.5. Existing commitments

In line with the commonly recognized fact that the energy sector is heavily based on the infrastructure, it was found that commitment to the legacy systems and infrastructure constitute one of they key impeding factors in advancing BRET.

> *"The problem is rather the infrastructure, the buy-ins you already have from your current system. Large utility companies have a lot of legacy and the existing systems."*- Charlotta Edeland, Vattenfall

The quote above refers to the existing systems of utility companies who must consider these commitments to the largest extent. They are the owners or operators responsible for functioning of the existing infrastructure, ranging from the physical electricity grid to the meters at residential houses, and own IT systems ensuring service to millions of customers. Accordingly, this factor was principally mentioned by the incumbents in the interview sample but also by other groups of actors who rely on incumbents in the advancement of any kind of BRET solution.

4.2.6. No proven business case

Furthermore, a recurrent issue referred to a certain extent by all participants is the necessity of having a business case for projects in BRET, which is currently not the case. Therefore, it seems to be necessary to have a business case, along with a functioning business model, before BRET can be launched:

> *"It was quite hard for us to see how that business could look like. That is the reason why we didn't continue with P2P"*– Catarina Naucler, Fortum

Moreover, the following quote further emphasizes the importance of a well-grounded good-quality business case;

> *"Motivations for the use of blockchain must be guided by a robust business model, clearly visible through efficiency gains on the business case"*- Ninad Mutatkar, Fortum

The presence of a proven business case carries importance also in relation to the aforementioned factors. This is because if it was present and the gains from it were considerable, it might solve also the other impeding factors, especially 4.2.2. and 4.2.5.

4.2.7. Insufficient allocation of financial resources

Many participants viewed scarce financial resources as another challenge in pursuing BRET projects.

This impeding factor is relevant for startups who are small actors and dependent on external venture capital funding, thereby not being able to rely on a profound financial basis:

> *"We certainly do want to influence that to the extent that we can. We are, however, a small company with limited resources"*- Scott Kessler, LO3

Additionally, in case of incumbents, funding of BRET and blockchain projects in general are restricted in a different way:

> *"In a big company, it is not really risk capital. It is your capital and you need to see how much you can spend on these topics [...] you have some money allocated to innovation topics, but those budgets are limited."*- Fabian Grote, E.ON

Ultimately, constrained allocation of financial resources is another factor why BRET does not advance to a greater extent. This is closely linked to another constrained allocation of resources, insufficient internal capacity and competence, which will be presented in the following sub-subsection.

4.2.8. Insufficient internal capacity and competence

Incumbents do not have the capacity to exclusively focus on BRET projects as they also have other priorities stemming from their day-to-day business and their ambition to investigate other new technologies. Moreover, when testing a new concept, the existing internal structures do not allow to follow-up with advancing it further as a result of insufficient allocation of capacity within the company. Lastly, neither incumbents' nor their contracted consultants' developers have enough expertise to implement BRET as they are not as familiar with blockchain as it would be required.

> *"We can have people in our Future Lab or Digital area, but there is always the challenge when they really want to do something that is more than a prototype. Then they need to find somebody from the business who is willing to work on it. Usually next to the day to day job"*- Fabian Grote, E.ON

This quote depicts the need for involvement of multiple departments within incumbent companies to advance a technology such as BRET. For that, BRET projects would need to be recognized to have major importance for the incumbents, thereupon creating the need to adjust internal structures.

4.2.9. Difficulty to find a governance model

The majority of interviewees highlighted finding a governance model as one of the challenges impeding BRET to further advance.

> *"A key point is how to establish a governance framework around blockchain since the regulators*[48] *want to have a responsible person. You cannot go to the regulator and tell them, well there is a new marketplace that we are using and it does not belong to anybody, it just belongs to everybody and nobody is really responsible for it"*- Kilian Leykam, Vattenfall

The quote above describes the most commonly mentioned problems related to this impeding factor: (1) appointing a decision making body which is difficult as all the actors have their own

[48] In the context of this study corresponds to institutional actors.

interests and have the ambition to retain or gain control over the new system, (2) and establishing a legal entity which is key in relation to the impeding factor 4.2.10. as the institutions require someone to be responsible in case a problem emerges.

4.2.10. Unfitting regulations

The arguably most pressing problem for market actors in the pursuit of BRET are the regulations.

> *"We are kind of mired down in fragmented regulations and this is holding everything back so much, which is a shame."*- Jonas Wallenius, Decentralized Camp Stockholm

According to the participants, the current regulations are unfitting to BRET for four main reasons: (1) it is not legal for prosumers to sell energy to their neighbours, (2) charging for using the grid is not dependent on the length of the grid that is actually used,[49] (3) data protection policies, including GDPR, are strict and make storing customer and other sensitive data on the blockchain platform risky or impossible, (4) regulation around tokens and cryptocurrencies is very strict and unharmonized even within the EU.

Ultimately, the regulations are widely considered in need of adjustments for BRET to advance. This can be illustrated by the following general quote:

> *"[Authorities] have not taken into account the technological lead that has been made in the last 10 years"*- Richard Rosenholtz, Nordic RegTech Association

4.3. Collaboration as the solution to overcome the impeding factors[50]

The aforementioned factors demonstrate that no actor can promote BRET alone, they do not act in isolation. The advancement of BRET is dependent on direct and indirect interactions among market actors and institutional actors. Hence, cooperation is the answer.

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[49] As of now, the grid fees are contingent exclusively on the fact on being connected to the electricity grid. However, what would be more suitable for BRET was if the grid fee was acknowledging the fact that the grid is less used since the distances of transported electricity decrease, thereby making the grid fee dependent on the used length of the grid.

[50] See 8.8.3. for an extensive list of quotes

4.3.1. Reluctance to act first

Currently, the ecosystem actors are waiting for others to do something. By cooperating, they can share information, distribute the effort in terms of finance and human resource allocation, as well as get reassurance from other actors about their future steps. They gain commitment of others which brings more certainty in regards to the future development of BRET's implementation.

This is particularly relevant when it comes to the unfitting regulations (4.2.10.). Many participants referred to institutional actors as lagging behind to what is happening on the market. They described this as a reason why they are not more active in BRET. Nevertheless, the reason why institutional actors might not be as active as other actors would prefer them to is that the indirect and even direct implications of the technology are not observable yet. In other words, the institutional actor is expecting the market actors to act before it acts which represents a chicken and egg problem.

4.3.2. Prerequisite of a multi-party involvement

Many participants believe that a future BRET solution must be developed in cooperation with others.

> *"We are very much aware that for this to work, every stakeholder has to agree on it"*- Fatuma Mohamed, Grid Singularity

The quote above emphasizes the importance of an industry-wide cooperation which would bring all stakeholders, including the identified groups of actors, together to coordinate efforts in one direction, which would need to be accepted by everyone. Importantly, the role of incumbents in such an agreement is particularly relevant.

> *"You cannot get a significant scale of microgrid 's set up without major utility buy-in."*- Evan Caron, Swytch

This quote highlights that any kind of BRET that has the ambition to scale, must include incumbents in the development process.

Furthermore, some participants revealed that a prerequisite for the success of a BRET platform is that it must be used by many actors. They said that it is able to fulfill its potential only if used by many actors.

> *"Blockchain in most cases only makes sense if you have different players in the industry aligned on using it"*- Kilian Leykam, Vattenfall

This quote reflects the need of the involvement of many actors.

4.3.3. Interest in working together, learn from each other and share

Finally, the willingness of actors to work together and share learnings is already observable.

> *"[Utilities] understand that there is a value in exchanging perspectives, opportunities, information, insights to make sure that whatever is developed is not fragmented, but instead is ready to be interoperable and standardized on European and global scales."*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital

The quote above refers to cooperation as a prerequisite for an emergence of a future standard as well as the already existing acknowledgement of the need of such cooperation.

4.4. Forms of interaction among actors[51]

4.4.1. One-time events

Most participants have attended or even organized several one-time events to learn more about blockchain projects in terms of what has been achieved so far and what the current market needs and trends are. These events can range from meetups and workshops organized by companies (e.g. IBM) or experts (e.g. Decentralized Camp Stockholm) to big conferences, such as EventHorizon, organized by companies (e.g. EWF) or institutional actors (e.g. Swedish Smart Grid Forum). During the conference "The future of electricity markets in a low carbon economy" organized by the Swedish Smart Grid Forum, we observed strong interaction between institutional actors, e.g. European Commission, startups and incumbents. Especially the startups were interested in regulatory sandboxes to promote BRET further. Another event type are hackathons, usually organized and sponsored by incumbents. For example, Vattenfall sponsored the Odyssey Hackathon.

[51] See 8.8.4. for an extensive list of quotes

4.4.2. Discussion fora and industry initiatives

Many participants have identified discussion fora and industry initiatives as crucial in sharing their experience in order to advance BRET.

> *"In a way, industry initiative like that are very important if it can succeed. I think they are prerequisite in a way."*- Fabian Grote, E.ON

This quote demonstrates that it is highly relevant for the industry to work together. As identified in 4.3.1., no one wants to act first or alone, which is why an industry initiative presents the perfect opportunity to advance and work towards an energy sector e.g. with less energy loses and less CO2 emissions.

4.4.3. Consortia

Identifying these discussion fora and industry initiatives as a good foundation for advancing with BRET, consortia are considered as even stronger interaction types to pursue BRET. Consortia are the creation of one platform that is open to all stakeholders, especially actors, thereby being similar to discussion fora. The difference is that consortia have a greater tangible alignment of its members as they are working on an actual technological or software service and aim to develop a standardized outcome. The following consortia were the most commonly referred to during the interviews: (1) Enerchain as a consortium for wholesale energy trading, (2) EWF, co-founded by Grid Singularity, as a consortia for BRET. The following quote emphasizes the need and purpose of consortia.

> *"The blockchain technology is quite young and it is still being developed. This is why the Energy Web Foundation has an ecosystem of affiliates which includes all stakeholders from transmission and distribution system operators, start-ups, regulators etc. Everyone is coming together and says we know we have this problem, we want to solve this problem, the only way is by coming together and contributing to the development of a technology we all agree on. And if we all agree on it, it becomes easier to change the policy in favour of the implementation of such technologies."*- Fatuma Mohamed, Grid Singularity

This demonstrates that members of consortia have the ambition to seek solutions to most pressing issues faced by the energy sector, e.g. connection of a growing number of RES generators to the main electricity grid. The intend to establish a standard that everyone accepts to facilitate the change of regulations. Companies are eager to join these consortia.

> *"We were quite excited to do it [join Enerchain] because we saw that almost all companies are doing it, [...] Same for the EWF. Here, E.ON joined because it was a big consortium and they had an interesting roadmap, but also other big players on board." - Fabian Grote, E.ON*

This demonstrates that without a consortium and its interaction of actors, the advancement of BRET will become difficult to achieve.

4.4.4. Accelerators and incubators

Incumbents make use of their own accelerators and incubators to support promising business ideas that arise within and outside of their company. It appears to be a common practice to build partnerships with the individuals who have the idea. One example is Green:field from Vattenfall, as demonstrated in the quote below:

> *"Green:field is an open innovation platform that brings together people with promising business ideas both within and outside Vattenfall, and helps people put their ideas into practice and integrate them at Vattenfall. The primary goal of green:field is to put business on a level playing field. In contrast to many standard accelerator programs or incubators, individual partnerships and coaching sessions are the main focus."*- Charlotta Edeland, Vattenfall

4.4.5. Partnerships

We acknowledge that partnerships are mentioned as crucial, especially for startups as they need contribution of incumbents to scale their existing business. This finding was supported by the quote below:

> *"We want to grow fast and probably in multiple markets, we need partnerships that help us do that. We don't think we can do that in multiple markets by ourselves."*- Scott Kessler, LO3

Yet, it is very important that these partnerships have a solid foundation, identified as sharing the same vision and purpose by both partners.

> *"We certainly do want to be aligned with our partners and we need to make sure that sort of the interest is the same that they have"*- Scott Kessler, LO3

This quote demonstrates that these are long-term partnerships through which they want to establish a sustainable business.

4.4.6. Direct interactions with institutional actors

Actors initiate interactions with institutional actors.

> *"We certainly do want to influence [the institutional actors] that to the extent that we can"*- Scott Kessler, LO3

This quote reflects that especially startups, who are driving the innovation, aim to have an impact of decision-making of institutional actors. As mentioned in 4.4.1., it was also observed during the attended conference of the Swedish Smart Grid Forum that startups were aiming to directly interact with institutional actors.

4.4.7. Monitoring

It is especially important for incumbents to monitor the market and its activities to stay updated with the technology and its potential to not fall behind.

> *"We will continue monitoring the activity"*- Charlotta Edeland, Vattenfall

This quote demonstrates that incumbents have monitored the activities within the market and will continue doing so in the future. Institutional actors are also monitoring the market to have an understanding of what is happening.

4.5. Complementary competences and assets in advancing BRET[52]

Having identified all these interactions among actors, recognizing the nature of mutual contributions of actors in the pursuit of advancing BRET is essential to explore the dynamics of BRET's advancement.

4.5.1. Financial resources

As mentioned in 4.2.7., startups have limited financial resources and are continuously looking for funding to accelerate the development of their business and extend their impact.

> *"They [utilities] have the fund to pay for some portion of our time and effort"*- Scott Kessler, LO3

[52] See 8.8.5. for an extensive list of quotes

This quote demonstrates that startups are interested in receiving the financial support from incumbents. Additionally, some incumbent participants mentioned their internal venture funds that supports diverse pilot projects. Therefore, financial support provided by incumbents can allow startups to accelerate their business development since they have the ability to hire more people, purchase more equipment and progress to further testing their ideas and technology.

4.5.2. Expertise

Identifying the expertise of all actors, the empirical data proved that no single expertise by itself is sufficient enough to advance with BRET alone.

> *"[Work on microgrids] requires a lot of business developers, civil engineers, electrical engineers, installers and experts in different domains. It is always a collaboration and startups could be part of it but [not alone]"*- Catarina Naucler, Fortum

This quote demonstrates that even though startups will probably be part of advancing BRET, they will not be able to achieve it by themselves. Utilities still have competent experts that are needed in the process as they have extensive knowledge of the current systems and their functioning by heart and have the power. Nonetheless, the expertise of consultancies and technology providers is also needed to support incumbents when trying out BRET.

4.5.3. Ideas and testing of ideas

When generating ideas and testing them, startups play a crucial role.

> *"Startups are very relevant for the energy industry because they are able to develop in their own ecosystems, in their own pace, in their own cost structure very fast use cases. They can prep prototypes. And this is what a utility company hasn't done before and the culture is very different. So, it is very good to have these external R&D vehicles for business case innovation or for disruptive innovations."*- Robert Schwarz, Pöyry

This quote demonstrates that the startups can develop and test innovative ideas and build prototypes, which incumbents usually do not have. Such dissimilarity is caused by different actors being at different stages of competence and knowledge in respect to BRET. As revealed in our empirical data, some startups even test such prototypes directly for utilities. Nevertheless, it was identified that the startups are diligent in protecting their intellectual property through, e.g. patents.

Additionally, consultancies and technology providers are testing the technology which generates more knowledge about BRET and furthers its maturity.

4.5.4. Customer base and distribution channels

Since startups are newly formed companies, they do not have the customer base and channels that are required to scale their business. Whereas, incumbents usually do not have the innovative solution directly at hand. Therefore, it adds value to work together.

> *"If you [as a startup] then go to the utility or relevant incumbent player and do it together with them or get a chance to access their channels, customers or sales, then you have a 100 times larger audience that you can talk to. [...] Startups are dependent on major players. They might not have the solution, but they have the customers"*- Consultant, Big 4

This quote demonstrates that when a startup gains access to incumbent's customer base distribution channels, it can reach to a critical number of potential customers. This will be important for the scaling process of startups and advancing BRET.

4.5.5. Ownership of infrastructure

When deploying BRET, startups benefit from relevant utilities' assets such as the existing infrastructure.

> *"This is why we benefit from having a partner because most of the time our partner owns the meter or has certain rights to use it or get data from it."*- Scott Kessler, LO3

This quote demonstrates that the beneficial partnership allows startups to use the infrastructure. Moreover, it already touches upon the regulatory compliance of utilities that startups can access, which will be disclosed in the next sub-section.

4.5.6. Basic regulatory compliance

In addition to having the needed rights for using data of the infrastructure, utilities also own the required retailing license, hence comply with regulation, while startups do not.

> *"They have regulatory license, they have retail license to sell electricity"*- Scott Kessler, LO3

This demonstrates another reason why startups benefit from partnerships with utilities as they can make use of the utilities' regulatory compliance.

4.5.7. Influence on the market

Utilities have major influence of what happens on the market.

> *"That depends if you have the utilities or grid operators on board because if you don't have them on board, then it is difficult. But today we mostly see the utilities and they dictate what happens in the market"*- Consultant, Big 4

This quote demonstrates that once the utilities are convinced of BRET, they can make use of their existing power to influence the market.

5. Discussion

This section will discuss the empirical data through lens of our theoretical framework (2.5.). First, we identify the innovation-decision stage of each actor. Second, we present the ecosystem map and elaborate on the interdependencies between the actors and the advancement of BRET. Third, the stage of the ecosystem is identified, and its implications are drawn.

5.1. Innovation-decision stage

For this BRET ecosystem, and hence BRET itself, to significantly advance, all actors must reach the same innovation-decision stage of the furthest actor. If the actors proceeded from similar understanding and with comparable expectations about the future evolvement, they could increase the quality of predictions. This would make them more open to commit resources for the advancement of BRET. Therefore, the identification of each actor's stage is paramount to determine their relative positioning in the five-stages scale represented below (figure 13).

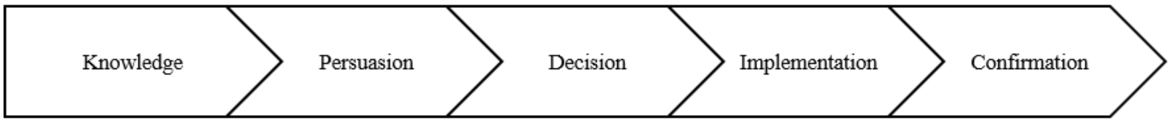

Figure 13: Innovation-decision stages by Rogers (1983)

Every actor is aware of BRET and recognizes its potential to disrupt the energy market to a different extent. Hence, all actors have reached a knowledge stage within the innovation-decision process (Rogers, 1983).

5.1.1. Startups

The startups included in the BRET ecosystem were founded with the objective to advance BRET. Hence, they have inherently completed the knowledge and persuasion stage. Since their core business is the development of BRET, they naturally evaluated its advantages and disadvantages and adopted BRET, therefore they passed the decision stage as well (Rogers, 1983). They have the required blockchain-related IT capabilities to implement BRET but still face limitations such as incomplete knowledge of the existing electricity systems and lack of access to these systems. Nevertheless, startups were identified with the potential to eventually disrupt the traditional energy system. Therefore, startups were identified to be at the beginning of the implementation stage (figure 14).

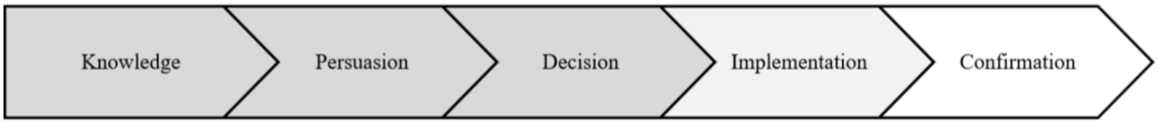

Figure 14: Startups' stage within the innovation-decision process

5.1.2. Incumbents

First, incumbents are generally interested in BRET and seek more information by joining industry initiatives and consortia such as the EWF. Second, they have not formed a final favorable or unfavorable opinion about BRET, as they consider it along existing and other alternative technologies to fulfill the same functions. Thus, they do not feel threatened by BRET. Consequently, they fulfill the characteristics of the persuasion stage (Rogers, 1983).

Rogers (1983) argues that the innovation-decision stages are sequential. However, our empirical data show that without having formed a rigid opinion about BRET, thereby not having completed the persuasion stage, incumbents already actively engage in activities that test the concept of BRET. This qualifies them for characteristics of the decision stage. While Rogers (1983) establishes that actors can skip the persuasion stage and move directly to the decision stage, we argue that it is possible that incumbents are concurrently in the decision and persuasion (figure 15).

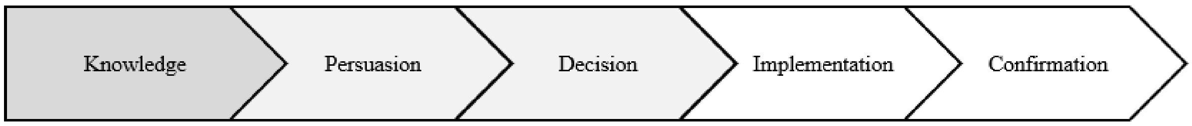

Figure 15: Incumbent's stage within the innovation-decision process

5.1.3. Consultancies and technology providers

It is important to note that consultancies and technology providers would not be the ones directly implementing BRET to the customers as they work at a business to business level. In the BRET ecosystem they work particularly with incumbents. Therefore, consultancies and technology providers aim to understand the relative advantage, compatibility and complexity of BRET to be competent to provide the corresponding consulting services, such as advising and supporting implementation of BRET. Hence, the characteristics within the persuasion stage are met (Rogers, 1983). They acknowledge the necessity of blockchain technology to significantly mature before fulfilling its potential to become widely adopted. However, they believe that the technology is already relevant for incumbents, their customers, to investigate. Some already support incumbents with initiating and running BRET pilot projects or test the technology themselves. Thereby they actively engage in BRET activities. Thus, as discussed in (5.1.2.), consultancies and technology providers are concurrently at the persuasion and decision stage (Rogers, 1983) (figure 16).

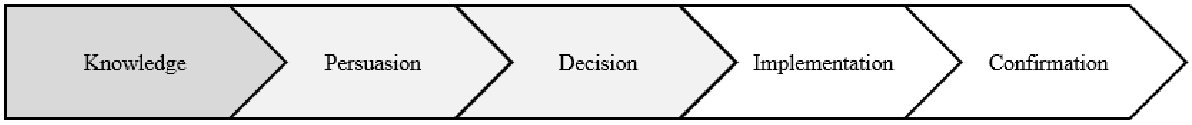

Figure 16: Consultancies' and technology provider's stage within the innovation-decision process

5.1.4. Institutional actors

Institutional actors are not implementing BRET for the customers, however they play an important role to provide the regulations permitting or restricting it. The institutional actors are interested in developing an enhanced understanding of BRET and seek information about it. However, currently the regulations do not allow for BRET, hence an update of the regulations is required to allow for it. The regulations have not evolved at this point because of the uncertainty about the future development of the immature technology. This demonstrates that the institutional actors are not willing to adopt the innovation yet. To adjust the regulations, they would need to become persuaded that this innovation does not represent inadequate risks to customers and fair competition in the energy sector.

Institutional actors have not participated actively in any activity regarding BRET, except seldomly granting regulatory sandboxes. Consequently, they have neither adopted nor rejected the innovation, hence have not reached the decision stage (Rogers, 1983). Therefore, we conclude institutional actors to be at the persuasion stage (figure 17).

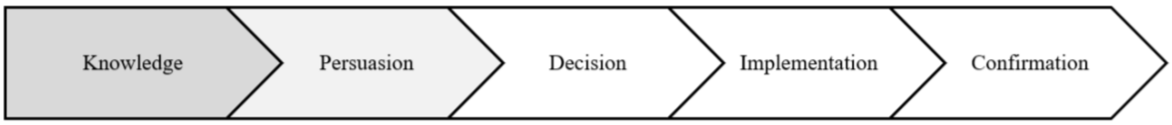

Figure 17: Institutional actor's stage within the innovation-decision process

5.1.5. Customers

BRET is currently tested and implemented at small scale, which is typical for innovative technologies at an early stage of development. The technology underlying BRET needs to further mature before reaching customers beyond innovators (Rogers, 1983). Additional impeding factors identified by this study (4.2.) contribute to the limitation of adoption beyond innovators.

Yet, customers are still recognized as important stakeholders that would become relevant if the technology advances along with the innovation decision stages of the ecosystem actors. It would be decisive to follow how customers create knowledge and form opinion about BRET, and potentially progress in the innovation-decision process. Eventually, the customers will become crucial for the advancement of BRET since they would be the actual adopters of the innovation.

5.1.6. Overview

The actors are in different stages within the innovation-decision process (figure 18). Persuasion stage represents the lowest stage that has not been passed by all actors,[53] hence emphasis needs to be put at this stage to advance BRET. This implies that the other actors have to focus on increasing interactions with them. If this knowledge is acted upon, it could contribute to solving the chicken and egg problem identified in "Reluctance to act first" finding (4.3.1.).

Finally, completing the persuasion stage by all remaining actors is therefore considered as a prerequisite for the advancement of BRET.

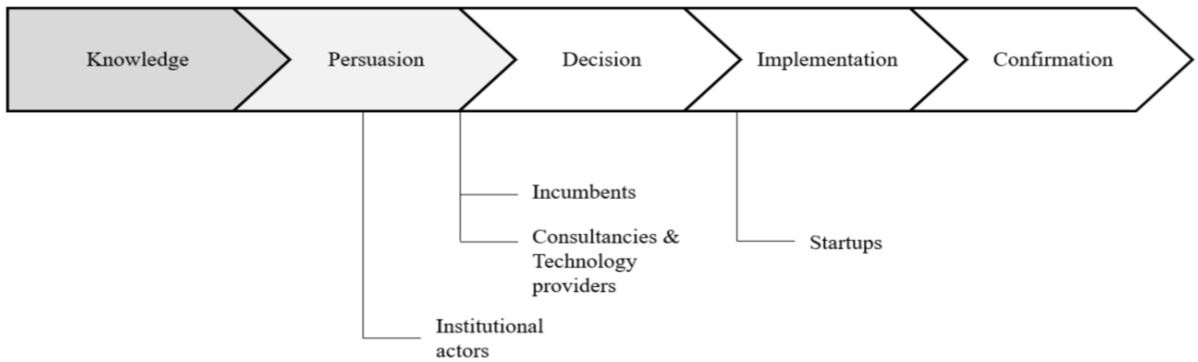

Figure 18: Overview of each of the four actors within the innovation-decision process

[53] This is due to the fact that the different actors are either interdependent or wait for other's action to reduce the uncertainty and risk associated with pursuing BRET by themselves, but also other impeding factors (4.2.).

5.2. Interdependencies

5.2.1. Map of BRET ecosystem

As a result of the analysis of the empirical data, we developed a map of the business ecosystem of BRET (figure 19). This map depicts (1) interactions among single actors whose innovation-decision stage was presented in the previous section, together with (2) the actors' interaction with the advancement of BRET.

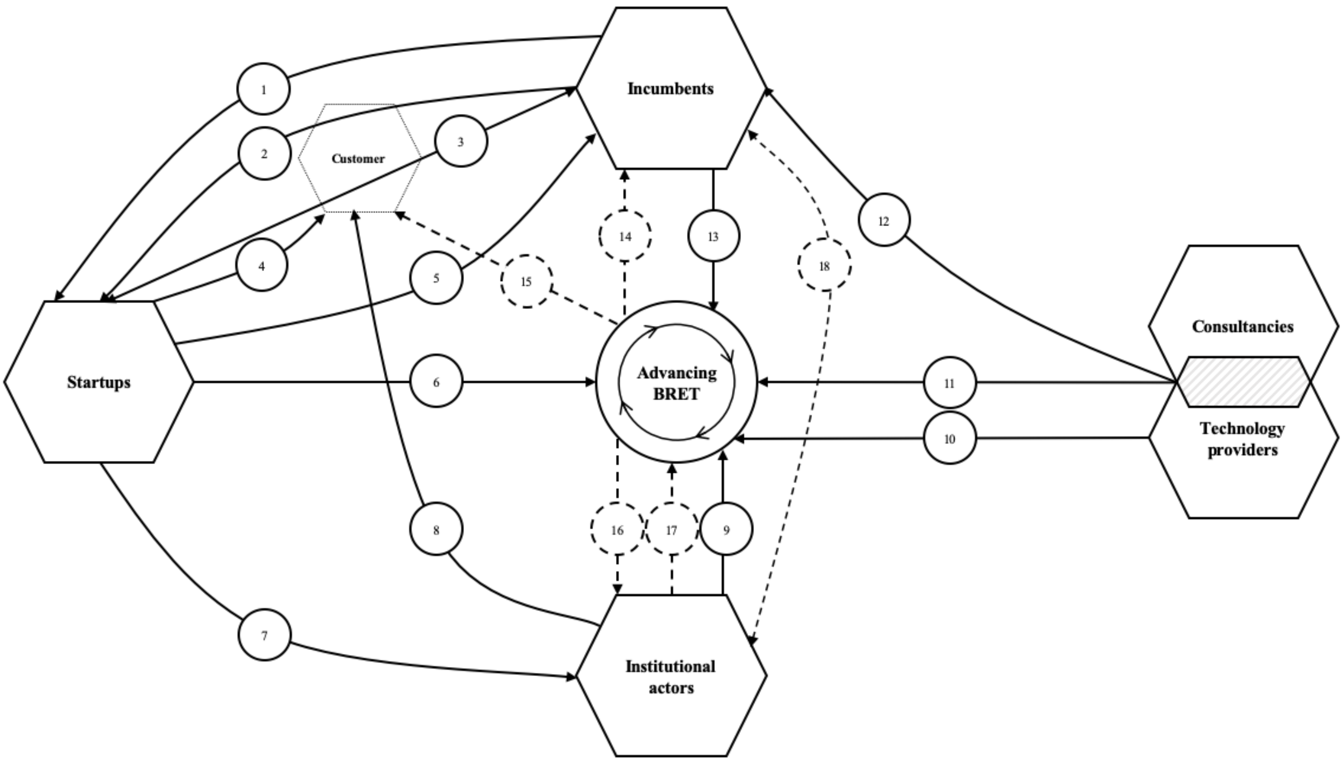

Figure 19: Map of BRET ecosystem

Legend I	
Symbol	Explanation
	The innovation
	The groups of actors in the ecosystem
	Identified future actors in the ecosyste
	Existing interaction
	Identified next steps required for furthe advancement of BRET
	Overlap of actors
	Ongoing advancement of BRET

Legend II	
No.	Activity
1	✓ Share experience and expertise about existing electricity systems ✓ Grant access to existing electricity systems, particularly the electricity grid ✓ Provide financial resources ✓ Support regulatory compliance by sharing e.g. retailing license
2	✓ Provide access to customer base and distribution channels
3	✓ Demonstrate and add value for customers of incumbents
4	✓ Allow for increased customer engagement, thereby democratization of the energy sector ✓ Support decarbonization, which is increasingly valued by customers

5	✓ ✓ ✓	"External R&D vehicles" Facilitate learning about BRET and its value Contribute with blockchain-related IT capabilities
6	✓ ✓ ✓	Drive the future development of BRET Test ideas and technology underlying BRET via PoC and pilot projects Initiate cooperation, especially consortia, to bring relevant actors together
7	✓ ✓ ✓	Initiate debate to promote acceptance of BRET Create knowledge on potential impacts of BRET fc customers and market mechanisms Enable efficiency in the energy sector by promotin; fair competition practices and reducing energy loss
8	✓	Protect the customers from potential negative implications of BRET
9	✓ ✓	Ensure fair competition within the ecosystem, e.g. preventing cartels Grant regulatory sandboxes, i.e. exception to existing regulations
10	✓ ✓	Develop technology while enhancing its maturity Initiate cooperative platform development
11	✓ ✓ ✓	Contribute with IT expertise and capabilities Build and test use cases Test technology itself
12	✓ ✓	Support knowledge accumulation on blockchain and BRET Assist in the implementation of blockchain-enabled solutions such as BRET
13	✓ ✓ ✓ ✓ ✓	Contribute with expertise of electricity systems Provide access to electricity infrastructure Monitor market activities related to BRET to stay updated and relevant Join consortia relevant for BRET Engage in PoC and pilot projects
14	?	Create necessity to consider BRET in their operations and services
15	?	Reach required scalability to become available for adoption by customers
16	?	Further demonstration of direct and indirect implications of BRET through PoCs, pilot and other kind of projects
17	? ?	Increased number of regulatory sandboxes Adjust BRET-relevant regulations
18	?	Prioritize BRET within their pre-established relationship

5.2.2. Overview of interdependencies

As discussed, all actors are at different innovation-decision stages (Rogers, 1983). This reflects their different knowledge, attitude and commitment. All three aspects can only evolve if interactions take place, which is why it is paramount that all actors interact with each other to enable the BRET ecosystem and hence BRET to advance. Such interactions create interdependencies since none of actors can advance BRET alone without the engagement and sharing of competencies and assets of others. Moreover, such interdependencies stemming from interactions have the potential to remove uncertainty. Accordingly, the interactions underlying the interdependencies, presented in figure 19, will be explored in this subsection. To be able to refer to the specific interactions, we put their respective numbers in square parentheses, [number], whenever they are discussed.

5.2.3. Incumbents and startups demonstrate strong interdependencies

Incumbents are an unsubstitutable actor in the ecosystem since they have the customer base and distribution channels, existing infrastructure, basic regulatory compliance and also decisive influence on the market. Those assets are a fundamental requirement for any scalable implementation of BRET which puts the incumbents in a unique position for BRET.

Nonetheless, in comparison to the incumbents, startups are better prepared to deploy BRET. This is by cause of them having the capacity to focus exclusively on its advancement, i.e.

development of the technology, testing it, trying new ideas, initiating cooperation [6]. Furthermore, their developers have blockchain-related IT capabilities, which the incumbents lack. Hence, this is valued by the incumbents who do not only lack blockchain-related IT skills but also internal capacity to independently pursue BRET activities. Therefore, they utilize startups as "external R&D vehicles" [5] by engaging with them in bilateral partnerships, incumbents' led accelerators and incubators, but also consortia. Through these forms of interactions, startups facilitate learnings of incumbents about BRET and its value.

In exchange, incumbents offer guidance to startups regarding electricity systems since they have the relevant experience and expertise [1]. They also provide startups with access to the electricity grid, allowing them to implement BRET in a natural setting [1], e.g. by connecting a microgrid to the main grid which is owned by incumbents.[54] This is key challenge since the access to the electricity grid is heavily regulated and incumbents are those who are authorized to operate the grid or sell electricity through specific licenses granted by the institutional actors [1]. Accordingly, incumbents can provide startups with access to their customer base [2]. All these assets and competencies allow startups to test their ideas and technology in practice through PoC or pilot projects [6]. This enables progression towards a scalable implementation of BRET, which is further enhanced through calibration of such concepts from the business and technological point of view from incumbents [13]. Two underlying reasons why incumbents are willing to share their assets and competencies [1, 2] were identified in this study. First, it is important to note that incumbents aspire to stay relevant while not becoming disrupted by this new technology. Hence, if BRET further advanced, it would become paramount to adjust the design of their operations and services [14]. Second, they see this sharing as a possibility to add value to their customers [3]. The latter is facilitated by startups who have identified two emergent customer values: increased engagement and decarbonization [4]. Nevertheless, as of now incumbents do not perceive the necessity to pursue BRET activities as an urgent issue since BRET is not mature enough to be able to be adopted by customers, i.e. it is not scalable. However, the required scalability has been identified as one of the next steps required for further advancement of BRET [15].

[54] As explained in 2.3.2.

5.2.4. Consultancies and technology providers and incumbents

As our empirical findings show, the technology's immaturity represents a major impeding factor in the advancement of BRET. Technology providers are, alongside startups, the ones who are responsible for the development of the technology. Therefore, they engage in building and refining technology platforms while inviting other actors to participate [10]. This is a paramount contribution to enhancing the maturity of BRET, hence its advancement. Additionally, technology providers together with consultancies contribute to BRET's advancement with their IT expertise in two ways. First, directly as they develop and test the technology and BRET projects. Second, indirectly as they develop and test the technology for alternative applications and blockchain in general [11]. This generates learnings or even an applicable technology design for an advanced BRET. What is also important to indicate is that consultancies and technology providers advice and support the incumbents with testing both BRET and blockchain in general [12]. This also allows them to accumulate knowledge on the aforementioned technologies [13] which further enhances the quality of their services.

5.2.5. Institutional actors and startups

Institutional actors want to ensure fair competition [9], which is crucial for the interactions within the ecosystem to occur. Moreover, they are charged with protecting customers, thereby preventing new practices and technologies from harming the customers [8]. Hence, before adjusting regulations allowing for BRET [17], they require more information on the potential impacts of BRET [16] which is still very scarce due to its novelty. Accordingly, knowledge creation on those impacts by startups [7], which is essentially stemming from testing the ideas and technology through PoC and pilot projects [6], is a paramount contribution to institutional actors.

5.2.6. Incumbents and institutional actors

It is important that startups engage in debate with incumbents [5] and institutional actors [7] to increase their awareness of BRET's benefits. As ultimately, incumbents and institutional actors need to enhance their understanding of BRET and recognize its benefits to prioritize BRET on their agenda. Prior to the establishment of this ecosystem, those two actors had an established relationship which has been assessed as highly relevant for any changes in the energy market. Hence, if incumbents and institutional actors prioritized BRET on the agenda of their mutual interactions [18], BRET could be significantly advanced. In other words, we consider the engagement of those two actors as a prerequisite for the advancement of BRET.

5.2.7. Concluding remarks on the interdependencies

The mutual contributions which are particularly significant among startups and incumbents demonstrate that they have co-evolved their competencies around the innovation, which is typical for companies in business ecosystems (Moore, 1993; Li, 2009). Thereupon, all these interdependencies demonstrate the existence of the BRET ecosystem (Aarikka-Stenroos & Ritala, 2017) and emphasize that not one actor can create the value alone.

5.3. Evolutionary stage of the BRET ecosystem

As shown in table 1 (2.5.), each stage has to fulfill three kind of challenges: overall leadership challenges, cooperative challenges and competitive challenges. Depending on whether those challenges were fulfilled, the ecosystem can be classified at one of the four evolutionary stages (Moore, 1996). It is essential to determine the stage of the ecosystem (figure 20) to be aware of what needs to be done to advance BRET and what challenges will become relevant for different actors.

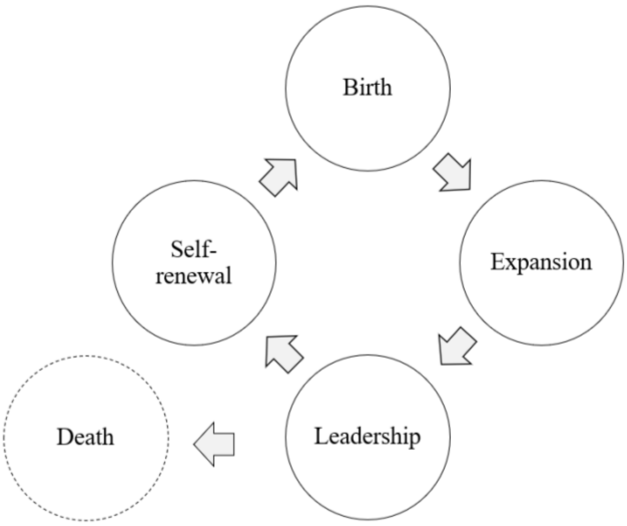

Figure 20: Stages of the Business Ecosystem (based on Moore, 1993)

5.3.1. Birth evolutionary stage completed

Cooperative challenges: cooperate to create a value proposition

When the BRET ecosystem emerged, the startups focused on the value proposition of BRET and how it can be best delivered to customers to enable them to trade their generated energy to their neighbors. When identifying the cooperative challenges, the EWF consortium was essential as it has provided a discussion and development platform for BRET. This has allowed suppliers and customers at a B2B level to work together to define the value proposition of BRET, which differs from the traditional way electricity is traded as it allows to include more customer engagement, decreases CO2 emission and existing energy loss. Therefore, the cooperative challenges of the birth evolutionary stage are completed (Moore, 1996).

Competitive challenges: protect ideas

The startups have patented their individual blockchain codes and services, hence completed the competitive challenge of the birth evolutionary stage (Moore, 1996).

Overall leadership challenges: value

As a consequence, a system and set of symbiotic relationships, that create a real value, have been established. Besides the overall leadership challenge of creating value, which is paramount to complete the birth evolutionary stage, a leader must emerge in this evolutionary stage. EWF and Grid Singularity, which co-founded EWF, were identified as a leader of the BRET ecosystem since it initiated this process of value creation. Apart from EWF, Grid Singularity founded an annual worldwide leading conference of blockchain in the energy sector, EventHorizon, in 2017.[55] As indicated above, all these interactions are crucial for the advancement of BRET. Accordingly, the birth evolutionary stage of the ecosystem is completed (Moore, 1993).

[55] Thereby bringing startups, incumbents, consultancies, technology providers and other experts in the energy sector together to discuss future options regarding renewable energy and blockchain.

5.3.2. Expansion evolutionary stage ongoing

Cooperative challenges: scale up

Moore (1993) identifies that established companies can make use of the developmental work of others to replicate existing ideas and distribute them across a wider market within this expansion evolutionary stage. As identified, incumbents use startups for idea generation in BRET. Startups conclude partnerships with incumbents to be able to use their assets (access to the electricity grid, regulatory compliance, customer base and distribution channels) and reach the wide market, i.e. critical mass. Despite startups and incumbents already sharing their resources and expertise, the diffusion of BRET to a critical mass will require additional criteria, particularly overcoming impeding factors (4.2.).

Competitive challenges: win over alternative solutions

Nevertheless, it is key for incumbents to continuously monitor startups to avoid a situation in which their customer base would be threatened. This is because the incumbents are part of alternative ecosystems in the energy sector, including the traditional electricity trading ecosystem which is a competing ecosystem to the BRET ecosystem. Therefore, competing for market share will become crucial for both ecosystems and especially for the actors who are part of both. Yet, it is important to acknowledge that the existing electricity systems are essentially owned by the incumbents which are therefore expected to continue playing an important role in the future, the question is to what degree and in which form. It is important that the traditional systems are challenged as parts of it are predicted to become obsolete (UN, 2010), hence need to improve. This is especially relevant in light of the energy trends of decentralization, digitalization and electrification.

Overall leadership challenges: critical mass

Currently, the value proposition of BRET is neither valued by a large number of customers nor has the immediate potential to scale up to reach the required the “critical mass”, which are criteria for completing the expansion evolutionary stage (Moore, 1996). Therefore, the BRET ecosystem is in the beginning of the expansion evolutionary stage (figure 21) which implies the need to increase the scale and scope of its synergistic relationships, i.e. promote interdependencies among actors (5.2.). This would make BRET more replicable and reliable (Moore, 1996).

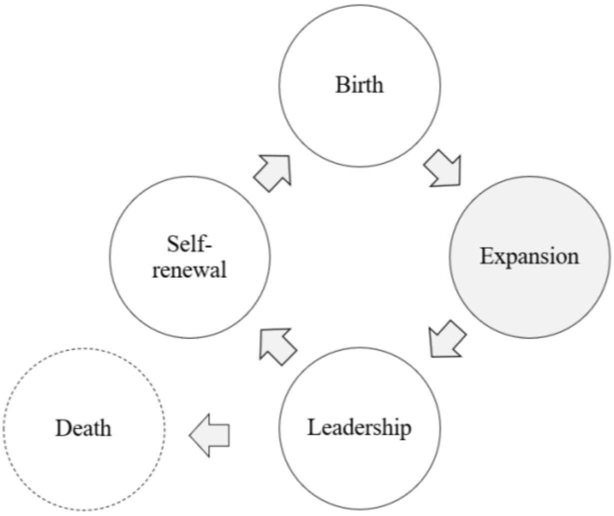

Figure 21: The stage of the BRET business ecosystem

Ultimately, all actors are self-interested which makes them consider their own situation and prospects (Moore, 1996). Therefore, the incumbents could make use of their current power and advantageous position on the market to stop the advancement of BRET to protect the traditional electricity trading ecosystem of falling to death phase. However, considering the current trends in the energy sector, it is inevitable that the traditional electricity trading ecosystem evolves and changes. This makes the BRET ecosystem a viable option.

If BRET became more established and accepted, it needs to be ensured that the market demand can be met (Moore, 1993), i.e. BRET would need to be scalable and reliable enough to satisfy the demand of all households interested in adopting it. When that is fulfilled, the affected suppliers need to realize that the next step will be to fight for leadership within the BRET ecosystem not only be among the existing actors, but also followers, who might have emerged. Therefore, it is crucial to keep control of customer relationships and important centers of value and innovation. However, before that will become relevant, blockchain still needs to mature.

6. Conclusions

6.1. Main results

The purpose of this study was to understand how BRET can be advanced within the energy sector. To achieve this, we adopted the business ecosystem approach in combination with the innovation-decision theory, which served us to identify key actors, interactions and related interdependencies required for this innovation to become further diffused and adopted.

Accordingly, we have identified four main findings derived from the BRET ecosystem developed in this study. First, there are four relevant actors that interact in the ecosystem: startups, utilities, consultancies and technology providers, and institutional actors. The interactions between them are a prerequisite for existing and further advancement of BRET. Second, the interactions identified in the ecosystem create interdependencies which lead to the fact that none of the actors can act alone to advance BRET. Third, startups are the drivers of BRET's advancement with Grid Singularity and EWF identified as potential BRET's ecosystem leaders. Lastly, incumbents and institutional actors are capable to halt the advancement of the BRET ecosystem.

6.2. Theoretical contributions

This study contributes to academic research in three ways.

First, given the novelty of the academic field of examining blockchain and its application in the energy sector, we contribute by creating knowledge within it. Taking the business perspective allowed us to look at this topic from a different angle than most scholars in this field. While focusing on one specific use case (BRET), we were able to analyze the blockchain perception of different actors and their actions in depth. This enabled us to draw detailed conclusions that help researchers to further understand this emerging field and allow for more follow-up studies.

Second, the ecosystem approach has not been widely used within academic research. Therefore, applying it to a combination of technology and sector, where it has not been used before, creates a valuable demonstration of the applicability of this approach.

Finally, by combining the ecosystem approach with the innovation-decision theory, we applied a unique theoretical lens. We have proven that strong conclusions can be drawn when these two are used together complementarily since we were simultaneously able to evaluate the role of and interactions among the actors. Furthermore, through the innovation-decision process theory, we have identified that it is feasible for individuals to be in two stages at the same time as it is possible that the stages blur into each other, similar to the ecosystem.

6.3. Practical implications

6.3.1. Regarding BRET

This study is highly relevant for practice due to the unpredictability of future development. This is stemming from factors that we have identified. We believe that this study can become a source for the decision-making process of the identified ecosystem actors. Hence, we derive three main practical implications that could provide guidance for the future advancement of BRET.

First, cooperation of incumbents and startups through sharing their resources, expertise and capabilities is needed to reach the critical mass of customers. Increased engagement of customers in the energy market could provide a foundation for a democratized energy sector and decrease of CO_2 emissions.

Second, interactions of technology providers and consultancies with other actors in the ecosystem are also necessary. They already invest resources in developing the blockchain technology and platforms while accumulating their knowledge of and experience with BRET. This makes them more competent to advise the other ecosystem actors to proceed and implement BRET solutions. This, in turn, leads to increasing the maturity of blockchain technology.

Finally, it is of utmost importance to note that institutional actors need to be persuaded by the other ecosystem actors. Following our finding that there is a reluctance among actors to act first, we conclude that other actors need to enhance interactions with the institutional actors. It is necessary for them to provide more opportunities for testing BRET such as regulatory sandboxes, and eventually to change regulation.

6.3.2. Beyond BRET

The ecosystem map developed and discussed in this study can provide valuable learnings to institutional actors and other relevant actors in comprehending and assessing blockchain applications in other sectors or other early technological innovations.

Other sectors

We believe that our findings are generalizable beyond the boundaries of the energy sector. Since blockchain remains an immature technology, knowledge on its implications and the way actors interact in the context of the technology is still scarce.

It can be assumed that this could be particularly relevant for other highly regulated sectors where regulations play a paramount role. Regulations do not only influence companies' regular operations but essentially have the decision power that is capable of fostering or preventing any innovation within the sector from happening.

Alternative technologies & in general

This case study can be relevant for the advancement of alternative new technologies with similar characteristics as blockchain. Technologies, that are complex, immature, difficult to understand at the outset, or changing the way actors interact, might benefit from the findings of this study. More specifically, our findings have the potential to make actors in alternative ecosystems recognize the importance of collaboration and seek to identify the most significant interdependencies.

Alternative technologies & energy sector

It should also be considered that the implications of this study might be relevant for a different technology in the exact same ecosystem that is discussed in this study. Accordingly, it is possible that an alternative new technology could advance at a faster pace than blockchain and become widely diffused in the energy sector and allow for residential P2P electricity trading. The advancement of such a technology could benefit from the knowledge created in this study about the identified relationships, the interdependencies among various actors as well as impeding factors.

6.4. Limitations

We have identified three main limitations to this study.

First, this study faces inherent limitations in connection with the composition of the interview sample. It was challenging to identify appropriate interviewees since only limited number of individuals within the utilities and other considered organizations are familiar with blockchain and BRET in particular. Furthermore, the coverage of interviewed startups focused on BRET could have been more extensive but due to availability and responsiveness of potential interviewees, we were limited. Hence, this study is limited by analyzing primary data collected only from three of the startups from the identified ecosystem.

Second, we conducted a single case study, which was, as discussed in the methodology section, appropriate in this case but inherently connected with trade-offs. A multiple case study with various use cases would allow for execution of not only within-case but also across-case analysis. This would enhance possibilities for further generalization.

Third, another methodological trade-off was made when choosing to adopt the qualitative approach. While we have identified interactions among actors and assessed some of them as more important than others, we did not determine the strength of the relationships by for example ranking them, which would be possible if the interactions were quantified. Such analysis would provide for an enhanced objectivity of this study.

6.5. Future Research

Since the research on blockchain application in the energy sector is still nascent, there are numerous opportunities for future investigation. Based on our findings, we have identified two main areas suitable for future research.

First, it would be valuable to further assess the importance of the identified impeding factors as well as the order in which they must be overcome for BRET to advance further.

Second, we suggest quantifying the identified interactions to determine their strength. This would allow to determine which are the most relevant and to evaluate the strength of their impact on the interdependencies among actors and BRET. We believe that conducting a longitudinal case study of one actor group, such as startups or incumbents, would be suitable to identify their interactions in more depth and see the impact in their day-to-day business.

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8. Appendices

8.1. Blockchain

8.1.1. Blockchain platforms

When Bitcoin became popular in 2008, the first blockchain platform got viral, which was in the financial sector (Crosby et al., 2016). It is important to differentiate the different blockchain platforms and not confuse blockchain with bitcoin, but to realize that bitcoin is one type of the blockchain platforms. Blockchain platforms can be divided into: (1) public, (2) consortium, and (3) private blockchain (Zheng et al., 2018). Depending on each platform type, the blockchain has different characteristics (table 3).

Characteristic	**Public Blockchain**		**Consortium Blockchain**	**Private Blockchain**	
Consensus determination	All miners		Selected set of nodes	One organization	
Read permission	Public		Could be public or restricted		
Immutability	Nearly impossible to tamper		Could be tampered		
Efficiency	Low		High		
Centralized	No		Partial	Yes	
Consensus process	Permission-less	Permissioned	Permissioned / Permissionless	Permission-less	Permissioned
Network openness	Anyone can join, read, write and commit; Hosted on public servers; Anonymous, highly resilient	Anyone can join and read; Only authorized and known participants can write and commit		Only authorized participants can join, read and write; Hosted on private server	Only authorized participants can join and read; Only the network operators can write and commit
Scalability	Low	Medium	High	High	Very High
Example	Ethereum, Bitcoin		Permissioned: Hyperledger, Tobalaba (specifically for energy)		

Table 3: Comparison of different blockchain platforms (Carson et al., 2018; Zheng et al., 2018)

When identifying the different characteristics, it is crucial to understand what those mean in this context. The most important differentiation of the individual characteristics is the consensus process, whether it is permissionless or permissioned, as this contains different network openness and scalability options.

Public blockchain platform

The most known and bust also most infamous blockchain platform bitcoin is, which is a public and permissionless blockchain platform (Carson et al., 2018). This combination means that anyone can join the network and has the ability to mine any blocks to the chains, which means validating and adding the transaction information to the chain (Carson et al., 2018). According to Carson et al. (2018) and Zheng et al. (2018) no intermediary, like a bank, is necessary in this type as the peers are mining for each other, which increases the trust as there is no central authority that has all the power, hence the platform is decentralized and generic. When miners are mining in this kind of P2P model, the blockchain compensates these participants with “tokens”, which is a crypto-asset specific for one application, and stake for any kind of increase in the future value. This compensation allows that model to be commercially viable (Carson et al., 2018). However, the actual mining process is rather slow and depends specifically on the chosen algorithm, see 2.2.3. consensus algorithms. Due to the structure and the mining process, it is nearly impossible to tamper this blockchain (Zheng et al., 2018). However, if one person owns more than 51% of the chain, that person can attack the blockchain (Zheng et al., 2018). Nevertheless, that is close to impossible to own that much of a chain. One big drawback of the public blockchain is that once you have lost your private key to enter the platform, which could be e.g. a USB-stick, you can never enter the platform again with your existing information (Zheng et al., 2018)

According to Carson et al. (2018), the difference of a public and permissionless blockchain to a public and permissioned blockchain is the scalability and network openness, where the latter is slightly more scalable, but still not a lot. Network openness means who is part of the system and who can take actions. Whereas public and permissionless means that anyone can join and also read, write and commit, public and permissioned means that still anyone can join and read, however not everyone, but only authorized parties can write and commit to the blockchain. This makes the permissionless blockchain highly anonymous and resilient (Carson et al., 2018).

Consortium blockchain platform

According to Zheng et al. (2018), consortium blockchain platforms are created by an existing network of people, mostly companies who work towards a common goal. Moreover, selected and not all nodes are able to determine the consensus. This type of blockchain is not as tamper-proof as the public blockchain, however is much more efficient, while being only partially centralized. Usually these kind of platforms are permissioned, but could potentially also work as a permissionless platform, however that would remove the incentive to build a consortium in the first place compared to a public blockchain (Zheng et al., 2018).

Private blockchain platform

The final option of a blockchain platform is a private one. It is very similar to a consortium platform, however instead of being owned by a network of companies or people, it is owned by one single entity (Carson et al., 2018; Zheng et al., 2018). Besides that, it is also fairly tamper-proof, more efficient compared to the public version, but centralized (Zheng et al., 2018). It can also be divided into permissioned and permissionless, with the permissioned type being the common one (Carson et al., 2018). In both platform types, everyone who is an authorized participant can join and read and the it is hosted on a private server. These types differ as the permissionless version allows everyone in the network to write, whereas the permissioned platform only lets the network operate write and commit (Carson et al., 2018).

Trade-offs

As described above, every platform has its own characteristics, which are valued differently by different operators and users. “The permissioned versions are faster, because the smaller number of players provides lower block processing time, known as latency. But fewer nodes also means less resilience” (Dick & Praktiknjo, 2019; p.6). Nevertheless, incumbents harness blockchain instead of being overtaken by it as they see the economic incentives and want to capture the value opportunities. “Therefore, the commercial model that is most likely to succeed in the short term is permissioned rather than public blockchain” (Carson et al., 2018; para.1).

8.1.2. Consensus algorithms

Proof-of-work

According to Andoni et al. (2019) and Zheng et al. (2018), PoW is a consensus algorithm that is used by Bitcoin and some other public blockchains. Here, the cryptographic puzzle is solved by miners who compete against each other to add the new block to the existing blockchain, which needs to be the longest chain to make it more secure. This is why they need a lot of computational power, hence consume a lot of electricity, as the fastest miner wins. Therefore, this algorithm is not the most sustainable one as a lot of energy is consumed for each transaction, which also makes every transaction very expensive. Once the mining was successful, the miner gets a financial reward and the new block is added to the blockchain. That new block is accepted by other miners when they try to add a new block to that chain. This algorithm is secure against malicious attacks as the attackers are constantly outpaced due to the fact that the longest chain survives. However, if an attacker owns more than 51% of the chain, those malicious nodes could have the power to rewrite the entire chain. Yet, the chances are very small that someone owns 51% of a chain. Furthermore, the transaction speed and finality is very poor for PoW. PoW can cover 7-20 transactions per second, whereas Visa could cover 24,000 transactions per second. Moreover, one block can be added every 10 minutes and it takes approximately 1 hour until it reaches finality in the chain. Blockchain developers are continuously searching for better solutions (Andoni et al., 2019; Zheng et al., 2018).

Proof-of-stake

Seeing the energy consumption as the biggest bottleneck of the PoW, developers came up with another concept, which is PoS (Andoni et al., 2019). According to Andoni et al. (2019), the computational power is not needed anymore in that algorithm as validators do not need to compete anymore, but actually get the transactions assigned. That assignment is depending on how much stake a validator already has in proportion to the other validators. However, this also means that if you have no stake in the system, you will most likely not get a chance to validate. Nevertheless, it provides a reason why the validation process could potentially become faster and also more secure as it decreases the likelihood of a malicious 51% attack. Moreover, as the validations are assigned, no additional financial incentives, such as newly mined coins, need to be set for validators to start computing because the financial reward of the transaction fee is good enough. Within PoS, malicious behavior and dishonestly can be penalized, which creates space for more preventing centralization and collusion (Andoni et al., 2019).

Proof-of-authority

Here, one or more members of the blockchain platform are granted permission to make changes to the blockchain. Therefore, PoA is similar to PoS, only where the stake equals the owner's identity, which provides the power to validate. Network members trust the authorized nodes to act on behalf of their interest. New validators can be added to the network based on votes. This algorithm represents a more centralized approach and is identified as appropriate for governing and regulatory bodies since it "may be useful in special use cases where security and integrity cannot be put at risk" (Andoni et al., 2019; p.150). The Energy Web blockchain already uses PoA and is able to scale its transactions up to several thousands due to its short confirmation time of 3-4 seconds (Andoni et al., 2019).

8.1.3. Smart contracts

Looking at smart contracts, it is worth mentioning that a human is actually coding the smart contract, hence depicts the interface, and is more likely to do a mistake than machines. This means that the blockchain could potentially agree to transactions if the requirements are met, however the actual requirements are set wrongly. As the principle of blockchain is that you cannot change any data, it is close to impossible to undo the smart contract. However, depending on the setup, one could potentially code an annulment of the conditions in order to undo the contract. Additionally, since a transaction based on smart contracts works in a way that the system is constantly checking for met requirements and not whether both parties have signed an actual contract, the legal aspect of a smart contract has not yet officially been identified. Philosophical nature of smart contracts: are smart contracts law in themselves or is human law superior to the smart contracts "law"? What if a mistake is made in the code, does it become legal to pursue self-interested "unfair" behavior which breaches the traditional law but is allowed by the platform design, be it by mistake or malicious interest of its author? (Pekárek, personal communication, March 29, 2019) This is a complex issue especially in regards to the lack of the general public understanding of blockchain. Nevertheless, smart contracts are highly valuable within blockchain applications as they facilitate the trading immensely.

8.2. Blockchain within the electricity sector

8.2.1. Blockchain's potential impact on energy companies' operations

Operation or process	The way blockchain would be applied	Opportunity when applying blockchain
Billing	Blockchains, smart contracts and smart metering can enable automated billing for consumers and distributed generators.	Utilities might benefit for energy micro-payments, pay-as-you-go solutions or payment platforms for prepaid meters.
Sales and marketing	Blockchains in combination with AI techniques (e.g. machine learning) can identify consumer energy patterns.	Utilities can provide tailored and value-added energy products based on the consumers' energy profile.
Trading and markets	Blockchain can enable distributed trading platforms that could be used within wholesale market management, commodity trading transactions and risk management.	It will reduce costs and benefit the operations to make it lean and more automated.
Automation	Blockchain could improve control of decentralized energy systems and microgrids.	This supports the adoption of local energy marketplaces enabled by localized P2P energy trading or distributed platforms. This can significantly increase energy self-production and self-consumption, which can potentially affect revenues and tariffs for network use.
Smart grid applications and data transfer	Blockchain can be used for communication of smart devices, data transmission or storage.	This enables secure data transfer and data standardization, which is relevant for smart grid applications.
Grid management	Blockchains could assist in network management of decentralized networks, flexibility services or asset management.	This could enable integrated flexibility trading platforms and optimize flexible resources, diminishing the need for expensive network upgrades, hence affecting revenues and tariffs for network use.
Security and identity management	Blockchain could safeguard privacy, data confidentiality and identity management by using cryptographic techniques.	This enables protection of transaction and security.
Sharing of resources	Blockchain could offer charging solutions for sharing resources between multiple users.	This allows e.g. sharing EV charging infrastructure and data or common centralized community storage.
Competition	Smart contracts could simplify and speed up switching of energy suppliers.	This enhanced mobility in the market results in increased competition, which might end up in reduced energy tariffs.
Transparency	Blockchain enables immutable records and transparent processes.	This allows for significantly improved auditing and regulatory compliance.

Based on Andoni et al., 2019

8.2.2. Blockchain-enabled payment within microgrids

Blockchain can facilitate the payment process by lowering money transfer charges and improving the security, which can be either handled through fiat currency or cryptocurrency (Andoni et al., 2019). Such cryptocurrency can be used to produce tokens as a digital asset (figure 22). In the energy sector, it is common to either use value tokens or utility token, which can represent e.g. kilowatt-hours (Wang et al, 2017; Andoni et al., 2019). The user within the microgrid has a digital wallet that is connected to the smart meter, thus enabling automated payment (Andoni et al., 2019).

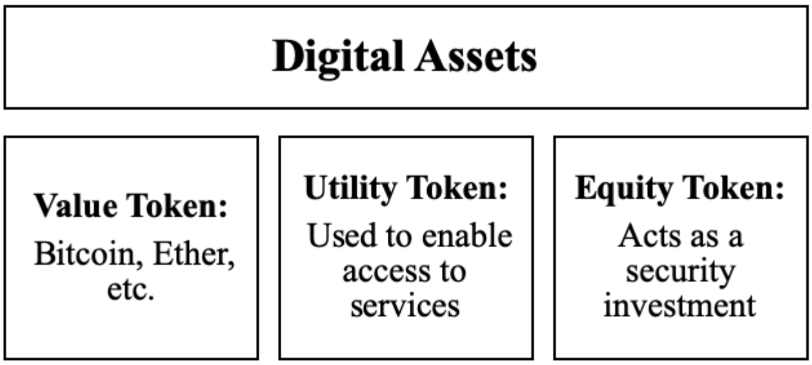

Figure 22: Different digital assets used with blockchain (Shafer, 2018)

8.3. List of participants in the pre-study

Participant	Organization	Position	Interview-type	Date
Claire Bogusz	Stockholm School of Economics	Researcher	Phone	11/02/19
Mihail Chigrichenko	Centigo	Consultant, blockchain in energy enthusiast	Personal	12/02/19
Issam Taleb	EY-Partheon	Consultant	Phone	13/02/19
Heinrich Frankenbach	Synpulse Management Consulting	Consultant	Phone	04/03/19

8.4. List of participated workshops during the pre-study

Workshop	Organized by	Location	Our position	Date
How to build blockchain apps	Openhack[56]	Stockholm	Participating observer	12/02/19
Towards the Tech of Tomorrow	IBM	Stockholm	Participating observer	14/02/19

8.5. Example interview guide

Interview guide for Fredrik Lundström, March 7, 2019, Stockholm

I. Introduction

1. How did you become interested in the energy industry?
2. Could you describe your position in Swedish Energy Agency?

II. Blockchain (BC)

1. What is your background in BC?
    1. Have you worked on BC projects?
2. Has SEA conducted analysis assessing potential of BC?
    1. At what level?
    2. Is there any report or material you could provide me with?
3. How do you think BC fits in the Smart Grids scheme?
4. Where do you see potential areas of BC application in energy transactions?
    1. How feasible are such solutions?
    2. Where is it going to be implemented first?
5. How do you see demand response interplaying with BC?

III. Relevant regulatory framework

1. Who are the regulators when it comes to energy and electricity in particular in Sweden?
    1. What is the relation between Swedish Energy Agency and Swedish Smart Grid Council?
2. Are the regulators driving change in the energy market? Could you compare it to other countries or one other country?
    1. Do they proactively change it with e.g. incentives / punishments?

[56] A collaborative community organizing tech meetups and hackathons

   2. How easy do you think it is to change regulations in the energy market?
3. How do you see the trajectory of the acceptance of BC by the government?
   1. By regulators in general?
   2. Do you think that e.g. direct P2P transactions will be allowed?
4. How does progress the Smart Meter roll-out in Sweden?
   1. What kind of Smart Meters are installed?
   2. What is the currently projected use of Smart Meters?
   3. Can you imagine a large-scale BC energy trading solution without the roll-out of smart meters completed?
   4. Can you imagine a local solution?
5. What is your view on microgrids and BC?
6. What is the legal framework when it comes to selling energy back to the grid by the prosumer in Sweden?
   1. What is the type of pricing?
   2. Are there changing conditions depending on peak hours?
   3. Do you expect the regulation to change in the future? If yes, how?
7. Do you know whether smart contracts would be accepted as a sufficient legal contract in the energy market for this kind of platforms?
8. Do you distinguish between energy trading and energy transacting? (If there is not a difference, I will go by trading)
9. How is energy traded in Sweden? Wholesale? To end consumers (B2B and B2C)?
   1. What platform is used? Is it only one or how many are there?
      1. Are there differences stemming from platform features more convenient for certain conditions? e.g. “density of customers” - South vs. North
      2. Is/are same platform/s used in other EU countries?
      3. What are the advantages and disadvantages of this platform?
   2. How has the existing system responded to the growing RES?
   3. What are the challenges of the current energy trading system?
   4. What are the planned changes to the existing system? Expected changes?
      1. How do you think the system will change in long run?
10. Do you have any visuals (e.g. flow chart) illustrating energy/electricity value chain?
    1. Terminology:

1. What difference do you see between saying P&U companies and energy companies except P&U encompassing other industries such as water?
2. Would you say that P&U differ from utility companies by comprising the upstream?
3. Do you distinguish between upstream-midstream-downstream or only upstream-downstream?

IV. Role of P&U companies

1. How do P&U companies perceive BC - as a threat or opportunity?
2. Do you know anyone in energy companies that is already thinking of the implementation of BC as a solution for their customers?
3. How do P&U react to BC?
    1. Do you perceive a growing cooperation with startups? If yes, of what kind?
    2. Do you think their reaction is adequate? If not - how should it look like according to you?
4. How a BC solution focused on energy trading could disrupt the current position of P&U companies?
5. How do you think looks the future role of BC companies?

V. Other

1. Who would you recommend me to contact to get more answers to these questions?

8.6. List of participants in the main study

Participant	Organization	Position	Group of actors in the ecosystem	Interview-type	Date
Scott Kessler	LO3 Energy	Director, Business Development	Startup	Phone	19/02/19
Fredrik Lundström	Swedish Energy Agency	Programme Manager	Institutional actors	Personal	07/03/19
Jonas Wallenius	Decentralized Camp Stockholm	Co-organizer	n/a	Personal	08/03/19
Tan Gürpinar	Technische Universität Dortmund	Research Associate - Distributed Ledger Technologies	n/a	Personal	08/03/19
Charlotta Edeland	Vattenfall	R&D Engineer	Incumbents	Personal	13/03/19

Marielle Lahti	Swedish Smart Grid Forum	Director Smart Grids and Electricity Markets	Institutional actors	Phone	13/03/19
Kilian Leykam	Vattenfall	Head of Business Development Trading	Incumbents	Phone	13/03/19
Samuel Sheehy	EDF Energy	R&D Analyst	Incumbents	Phone	13/03/19
Camilo Perez	KPMG	Manager, Advisory - Digital Transformation & Innovation	Consultancies and technology providers	Personal	14/03/19
Martin Knaack	Microsoft	Digital Advisor	Consultancies and technology providers	Phone	15/03/19
Catarina Naucler	Fortum	R&D Manager	Incumbents	Phone	15/03/19
Evan Caron	Swytch	Managing Partner	Startups	Phone	15/03/19
Richard Rosenholtz	Nordic RegTech Association	Chairman	n/a	Phone	18/03/19
Elisabeth Kellerer	E.ON	Venture manager and Data scientist	Incumbents	Phone	18/03/19
Ninad Mutatkar	Fortum	Project Manager - Innovation Accelerator	Incumbents	Phone	18/03/19
Consultant, Big 4	n/a	Consultant	Consultancies and technology providers	Phone	18/03/19
Sergej Kotliar	Bitrefill	Founder and CEO	n/a	Personal	19/03/19
Alexandra Bådenlid	Fortum	Digital Transformation Manager	Incumbents	Phone	20/03/19
Fatuma Mohamed	Grid Singularity	Energy Engineer	Startups	Phone	22/03/19
Robert Schwarz	Pöyry	Principal Consultant	Consultancies and technology providers	Phone	22/03/19
Zdeněk Pekárek	Eurelectric Blockchain Platforms & Inven Capital	Independent advisor	n/a	Personal	29/03/19
Fabian Grote	E.ON	Senior Energy Economist, Energy management	Incumbents	Phone	05/04/19

8.7. Coding Scheme

1. **Main category: blockchain technology application in p2p trading and microgrids**
    a. Benefits of blockchain
    b. Projects
        i. White paper
        ii. PoC
        iii. Pilot
        iv. Simulation
        v. Unspecified types of projects
    c. Same functionalities of other technologies
    d. How it works/would work
    e. Future of blockchain application, incl. PoW
    f. Blockchain maturity, e.g. scalability
    g. Situation on the market
    h. Business case and business model
    i. Standard
    j. Regulation as a challenge
    k. Other challenges of blockchain
2. **Main category: blockchain technology in the energy sector**
    a. Benefits of blockchain
    b. Projects
        i. White paper
        ii. PoC
        iii. Pilot
        iv. Simulation
        v. Unspecified types of projects
    c. Same functionalities of other technologies
    d. On how it works/would work
    e. Future of blockchain application in the energy sector
    f. Blockchain maturity
    g. Situation on the market
    h. Business case
    i. Standard

j. Regulation (as a challenge)
k. Other challenges of blockchain

3. **Main category: startups**
   a. Resources
   b. Current role and functions
   c. Future role and functions (ambition and prospects)
   d. Motivation
4. **Main category: incumbent energy providers**
   a. Experience with blockchain
   b. Resources
   c. Current role and functions
   d. Future role and functions (ambition and prospects)
   e. Motivation
   f. Attitude towards blockchain
5. **Main category: other relevant market actors such as consultancies and technology providers**
   a. Current role of consultancies
   b. Current role of technology providers
   c. Other related to consultancies
   d. Other related to technology providers
   e. Related to other actors
6. **Main category: interaction between market actors**
   a. Incumbents (give) to startups
   b. Startups (give) to incumbents
   c. Incumbents to incumbents
   d. Everyone to everyone
   e. Form of interaction
      i. Accelerators
      ii. One-time events (hackathons, conferences, workshops)
      iii. Open source innovation or open innovation, incl. discussion platforms
      iv. Partnership
      v. Consortium
      vi. Acquisition
      vii. Incumbents with universities
   f. Other actors

i. Incumbents with consultancies

ii. Incumbents with technology providers

7. Main category: regulation/legislation and involvement of public institutions in blockchain application in the energy industry

a. Regulation of blockchain / cryptocurrencies

b. Regulation of blockchain in the energy sector

c. Aspects of regulation/legislation:

i. Actual legalization of “physical” P2P trading

ii. Data protection

iii. (Decentralized) responsibility

d. Regulatory sandboxes

e. Creation of discussion platforms

f. Research staying updated

g. Opinion

h. Other types of interactions with incumbent energy providers

i. Other types of interactions with startups

8. Main category: governance of blockchain projects

a. Design of governance

b. Actual governance (process)

c. Challenges

d. Best practices

e. Parallel to other industries

9. Main category: end customer

a. Customer needs and preferences

b. Customer’s lack of awareness

8.8. Extensive list of quotes (complementary to section 4. Empirical findings)

8.8.1. Complementary list of quotes to section 4.1.

Actors' motivations to participate in BRET activities		
Section	*Heading*	*Quote*
4.1.1.	Incumbents	*"Why blockchain is being explored to such a large scale, especially by the utilities, is because of the technology disruption and new business models that could emerge around managing and delivering electricity."*- Ninad Mutatkar, Fortum *"My task is of course to keep track of what is happening with this technology [blockchain] and do we find some use cases where it can bring value to Fortum."*- Alexandra Bådenlid, Fortum *"I think the energy companies [...] should look in this kind of things to stay relevant and pursue further investigations, try out things and so on, to have that ready when blockchain will be even more mature and well established."*- Martin Knaack, Microsoft *"One of thes developments we explore is the blockchain technology [...] we found this interesting disintermediation potential of the technology and this drew our interest. So, we were looking where we depend on intermediaries and where we are the intermediaries and what we can make out of that for us."*- Elisabeth Kellerer, E.ON *"I think it's highly relevant to experiment with the technology. [...] Conducting more research and building PoCs are steps in the right direction"*- Charlotta Edeland, Vattenfall
4.1.2.	Startups	*"We are trying to democratize the electricity market, so that everybody could be a participant, especially the prosumers and consumers at the distribution level"*- Fatuma Mohamed, Grid Singularity

		"I convinced the folks [at Trailstone] that energy and blockchain, distributed energy resources and new technology was going to be very disruptive to the current energy market design [...] as well as support zero carbon and net zero energy systems. So, for the last two years, I have worked on Swytch."- Evan Caron, Swytch *"[Swytch] identifies [...] non-efficient or inefficient ways of how the energy markets have evolved over the last 15, 20 years [..] how new technology disrupts and changes traditional utility business models"*- Evan Caron, Swytch *"We are trying to take a holistic view of how the energy market should operate, how energy technology should be integrated and what is required for next generation energy systems to act in ways where they provide coordinated cooperative services as a shared service"*- Evan Caron, Swytch
4.1.3.	Consultancies and technology providers	*"I advised a utility company in exploring different options of using blockchain. So, it was the typical setup: hello, we heard about blockchain, we think it is cool and what can we do. This is basically 50% of the emails we get here."*- Consultant at Big 4 *"As the implementation of the technology is not self-explanatory at all, you need consulting services that lead to significant revenues at IBM side"*- Tan Gürpinar, Academia *"I do not think that there are players with the capabilities that we have, so definitely there is some investment"*- Martin Knaack, Microsoft *"Often it is still a solution looking for a problem, you can take IBM for example"*- Sergej Kotliar, Blockchain Expert
4.1.4.	Institutional actors	*"The fundamental question is 'what purpose does the regulation serve' and the answer would be to protect the customers and the society. To protect them in ways they should not be expected to understand in detail, but which should serve a real-world objective of the society. And potentially to give the users an option to confirm explicitly that they understand the risks and to opt out"*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital *"The regulator's role is very important to keep it regulated that it is really an open foundation for a technology that can be used by anyone"*- Fabian Grote, E.ON

		"There needs to be an update to the regulations on what is permitted of what is allowed"- Richard Rosenholtz, Nordic RegTech Association *"We think that it is very interesting to see this new phenomenon that blockchain is and a new way to interact between people and organizations. It points to, as we see it, a decentralization of the energy system potentially. [...] However with this speed of development in technology one never knows what will happen."*- Marielle Lahti, Swedish Smart Grid Council

8.8.2. Complementary list of quotes to section 4.2.

Impeding factors preventing actors to pursue BRET activities to a greater extent

Section	*Heading*	*Quote*
4.2.1.	Inflated non-specific expectations	*"There are so many people adopting around that [blockchain] and talking tech. That is just a wrong way to start."*- Jonas Wallenius, Decentralized Camp Stockholm *"We need to be more specific and speak about things which are not buzzwords but about things which are achievable, which are tangible"*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital
4.2.2.	Uncertainty about substitutability of blockchain functionalities	*"It could work without blockchain, it would be slower, it is not going to be 100% decentralized"*- Fatuma Mohamed, Grid Singularity *"Swedish power company to implement blockchain [...] what can they only do with the blockchain or what can they do better with a blockchain. And if you can answer that question, it is going to be a hype."*- Jonas Wallenius, Decentralized Camp Stockholm *"Really make up your mind that there are not any other ways to do it which might be better suiting microgrids"*- Elisabeth Kellerer, E.ON
4.2.3.	Blockchain is an immature technology	*"One of the learnings, that what we did, the blockchain technology is quite immature"*- Catarina Naucler, Fortum *"If [...] it is actually easier to build something with blockchain than without, then of course everyone will build everything with blockchain"*- Alexandra Bådenlid, Fortum

		"Proof of Authority will be more helpful in reducing the costs, ensure security and reducing the number of nodes that you need for a very safe system"- Robert Schwarz, Pöyry *"Although blockchain has the potential to provide scalability, reduce transaction costs and increase process automatization, the technology is currently not mature enough to do that."*- Charlotta Edeland, Vattenfall <u>Scalability and performance specifically:</u> *"For now yes, technology is not scalable yet. Not scalable enough to handle the extensive number of transactions required in the case of peer to peer energy trading"*- Fatuma Mohamed, Grid Singularity *"First, [what is necessary is] the development of blockchain technology that can keep up with the scale and speed of energy trading."*- Samuel Sheehy, EDF *"I think they have to overcome their technical challenges, especially related to performance [of blockchain applications]"*- Martin Knaack, Microsoft
4.2.4.	No standardized technological design or platform	*"I think there must be more standardization. There are many ideas and many technologies out there and you don't know which one is really taking off."*- Martin Knaack, Microsoft *"It is a force of nature for software businesses to adopt common platforms because it saves costs and grows revenue: standardized, open architectures lower the costs of software development and maintenance, accelerate roll-out of new products and services, and simplify activities such as hiring new developers or ensuring cybersecurity. A convergence and adoption of standards will certainly happen."*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital *"What will be important is the interoperability of the different blockchains that you cannot have something that is completely stand alone in a market"*- Martin Knaack, Microsoft *"I think you need to come up with standard [...] or systems that connect disparate systems together that speak the same or similar language [...] without that it is going to be very difficult"*- Evan Caron, Swytch

4.2.5.	Existing commit-ments	*"The problem is rather the infrastructure, the buy-ins you already have from your current system. Large utility companies have a lot of legacy and the existing systems."*- Charlotta Edeland, Vattenfall *"I also think blockchain "hybrid" technology will be incorporated in existing processes and systems in companies. I think IT software developers will start to use a kind of blockchain technology in their normal processes, in their normal systems. I think that is the way forward"*- Catarina Naucler, Fortum
4.2.6.	No proven business case	*"Motivations for the use of blockchain must be guided by a robust business model, clearly visible through efficiency gains on the business case"*- Ninad Mutatkar, Fortum *"For it to actually impact society, there needs to be value to it"*- Jonas Wallenius, Decentralized Camp Stockholm *"It was quite hard for us to see how that business could look like. That is the reason why we didn't continue with P2P"*- Catarina Naucler, Fortum *"The clearer it will become [...] that there is really potential to generate [...] business cases, then the more quickly resources will be allocated to it also from our side. And I think that is true for most of the energy companies"*- Fabian Grote, E.ON *"You have limited allocation on different [innovation] topics. So, if you want to spend on one topic much more, then at some point you need to get to a business case."*- Fabian Grote, E.ON *"We always need to reasonably argue that there is a business case. If there is none, it is not going to happen."*- Jonas Wallenius, Decentralized Camp Stockholm
4.2.7.	Insufficient allocation of financial re-sources	*"In a big company, it is not really risk capital. It is your capital and you need to see how much you can spend on these topics [...] you have some money allocated to innovation topics, but those budgets are limited."*- Fabian Grote, E.ON *"We certainly do want to influence that to the extent that we can. We are, however, a small company with limited resources"*- Scott Kessler, LO3

4.2.8.	Insufficient internal capacity and competence	Other priorities: *"Many energy companies put their digital development at the forefront where blockchain is one of the many technologies that are being tested, implemented, and used in different use cases."*- Charlotta Edeland, Vattenfall Absence of internal structures for this kind of innovation: *"We can have people in our Future Lab or Digital area, but there is always the challenge when they really want to do something that is more than a prototype. Then they need to find somebody from the business who is willing to work on it. Usually next to the day to day job"*- Fabian Grote, E.ON Not enough expertise: *"How easy is it to build, how many developers – our developers or of the consultants that we use – do know the blockchain, do they know how to build blockchains and most don't"*- Alexandra Bådenlid, Fortum *"Utilities, historically required to deliver highest levels of reliability and accountability, might struggle to introduce digital 'agile' elements into their internal culture, since they still need to deliver the core services reliably and 'accountably' at each moment. This is why utilities often partner with startups and/or establish innovation departments with somewhat different culture and way of working, to attract and retain expert talent incompatible with the traditional way of delivering results."*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital
4.2.9.	Difficulty to find a governance model	*"Is there an authority in the middle? Do we have a village council? Is there someone allowing a new person in? This is a governance issue."*- Jonas Wallenius, Decentralized Camp Stockholm *"You need to tie the blockchain identity to the power source. That is a critical governance problem to solve."*- Jonas Wallenius, Decentralized Camp Stockholm

		"Blockchain technology has not brought so much value because we have not managed to put all the management into the blockchain platform, but we have needed to have this centralized governance structure"- Alexandra Bådenlid, Fortum *"A key point is how to establish a governance framework around blockchain since the regulators want to have a responsible person. You cannot go to the regulator and tell them, well there is a new marketplace that we are using and it does not belong to anybody, it just belongs to everybody and nobody is really responsible for it"*- Kilian Leykam, Vattenfall *"Creating a kind of governance structure around the blockchain [...] is actually not so easy to establish because you need some form of legal entity with a decision structure."*- Kilian Leykam, Vattenfall *"It is an emerging technology and it can be shaped not only on thetechnology level but also on the governance level. [...] Governance of decentralized technologies could learn from experience in general project management, which uses the disparaging term 'design by committee', or even the proverb 'too many cooks spoil the broth'. Cryptocurrencies and blockchain platforms will likely adopt best practice developed by open source software platforms, which often have centralized, non-profit organizations at their core."*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital
4.2.10.	Unfitting regulations	Overview: *"We will need to see a lot of cases coming up to the courts and showing how the legal system will handle this. And it is not until then when you can predict a risk of going into this type of projects."*- Alexandra Bådenlid, Fortum *"Looking at the financial, as well as energy market regulation in most countries, P2P transactions are pretty difficult to implement"*- Kilian Leykam, Vattenfall *"[Authorities] have not taken into account the technological lead that has been made in the last 10 years"*- Richard Rosenholtz, Nordic RegTech Association

"Public or financial sector or utility or energy industry should be allowed to work with this and not be seen as doing shady business or being outside of the norm or law. That is what is needed."- Richard Rosenholtz, Nordic RegTech Association

"We are kind of mired down in fragmented regulations and this is holding everything back so much, which is a shame."- Jonas Wallenius, Decentralized Camp Stockholm

"It is with a heavy sort of regulatory hand. So it is a little bit more difficult to, as a startup when we are trying to figure out how to do things"- Scott Kessler, LO3

"Legislation or regulation could help speed up that process"- Alexandra Bådenlid, Fortum

Not legal for prosumers to sell electricity to neighbour:

"It won't be successful unless we have regulation that make it really easy to setup this [...] P2P networks"- Jonas Wallenius, Decentralized Camp Stockholm

"Due to the energy market framework it is a lot more difficult to implement a real use case for blockchain on the B2C level compared to the B2B level"- Kilian Leykam, Vattenfall

"You cannot sell energy to your neighbor because you need a license for that. That is a very big challenge"- Fabian Grote, E.ON

"This requires a change in policy. For instance to facilitate P2P energy trading, there should be some change in the existing infrastructure"- Fatuma, Grid Singularity

"Depending on the definition, but it is few microgrids in the Nordics today. Electricity is a regulated business and it is not really easy to just 'sell to your neighbour'"- Catarina Naucler, Fortum

Charging for use of the grid is not dependent on the length of the grid that is actually used:

"If you would be able to use the already existing infrastructure but somehow not pay the full fee as you are not transporting the electricity such a long way, I think that could speed up the adoption of microgrids"- Alexandra Bådenlid, Fortum

Data protection:

"If we now say all these data go to blockchain, I assume that there are also a lot of regulatory hurdles around that"- Fabian Grote, E.ON

Regulation around tokens and cryptocurrencies:[57]

"As soon as you start your own coin or money [...] you get into the heavy banking regulation which requires a lot of work and it is quite expensive to be aligned with"- Alexandra Bådenlid, Fortum

Unfitting regulations in combination with other factors:

"When we tested, we have noticed that it works technically, but it also needs a lot of governance and there were also the tricky things around regulation"- Alexandra Bådenlid, Fortum

"The best thing you can do is being recognized by the authority, so more people are working on the technology and its security"- Richard Rosenholtz, Nordic RegTech Association

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[57] This becomes relevant, when tokens are chosen as a payment system. It is very likely that tokens will be part of the P2P electricity trading to enable more automatization, which will lead to easier handling for the customer and supplier.

8.8.3. Complementary list of quotes to section 4.3.

Collaboration as the solution to overcome the impeding factors

Section	*Heading*	*Quote*
4.3.1.	Reluctance to act first	*"It is always the question of what happens first. Does really regulation push something or is the regulation lagging?"*- Fabian Grote, E.ON *"Global electrical energy systems are complex. They have so many interdependencies that are required to make them work."*- Evan Caron, Swytch
4.3.2.	Prerequisite of a multi-party involvement	*"Blockchain in most cases only makes sense if you have different players in the industry aligned on using it"*- Kilian Leykam, Vattenfall *"Blockchain is an institutional technology and requires many parties to work together [...] Microgrids is one example, you cannot do it by yourself. You need many different contributing stakeholders"*- Charlotta Edeland, Vattenfall *"I think it can only really succeed, if it is open in a way. The question now is what is open? It doesn't mean necessarily fully open source, where for example consumers need to participate. But open in a way that it is open for everyone who wants to participate in the ecosystem."*- Fabian Grote, E.ON *"I would be very surprised if the near future doesn't bring solutions in some of these areas that are seen as the problem areas today. [...] It just depends on how many people are working on these different technologies [...] At a residential level, that has mass adoption potential, it needs to be something like that. It cannot be something that only two or three companies develop together."*- Fabian Grote, E.ON *"We are very much aware that for this to work, every stakeholder has to agree on it"*- Fatuma Mohamed, Grid Singularity *"I would say it makes sense to find a solution on the vertical energy value chain to have a collaboration and to set joint standards that everyone will use in the future."*- Consultant, Big 4

		Incumbents must be part of whatever is going to be developed: *"In the energy industry, even in the first step, you already have to talk to the infrastructure owners or providers. In other industries you might come up with solutions without the incumbents"*- Consultant, Big 4 *"You cannot get a significant scale of microgrid 's set up without major utility buy-in."*- Evan Caron, Swytch
4.3.3.	Interest in working together, learn from each other, and share	*"And we realized that when you don't know something and you want to learn, it is very good to work with the ones who know better. So, we tried to find out who could learn and work with us."*- Catarina Naucler, Fortum *"[Utilities] understand that there is a value in exchanging perspectives,opportunities, information, insights to make sure that whatever is developed is not fragmented, but instead is ready to be interoperable and standardized on European and global scales."*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital

8.8.4. Complementary list of quotes to section 4.4.

Types of interaction among actors		
Section	*Heading*	*Quote*
4.4.1.	One-time events	*"Vattenfall has been a sponsor of the Odyssey Hackathon – billed as one of the largest AI and Blockchain hackathons in the world with over 6000 active participants."*- Charlotta Edeland, Vattenfall
4.4.2.	Discussion fora, industry initiatives	*"There is a possibility to build a discussion platform where entities of all kinds would come and share their experience, the problems they run into [...] and seek partner if that is relevant. And at the same time, everyone would be informed of what is happening [...] from the beginning, there was definitely a portion of the discussion explicitly including external startups, new initiatives, new platforms"*- Zdeněk Pekárek, Eurelectric Blockchain Platform and Inven Capital *"In a way, industry initiative like that are very important if it can succeed. I think they are prerequisite in a way."*- Fabian Grote, E.ON *"Every stakeholder in the industry is working together."*- Fatuma Mohamed, Grid Singularity

		"So, you see the role of startups fundamental in this process?" "Yes, startups, but also in a way industry initiatives, consortia"- Fabian Grote, E.ON
4.4.3.	Consortia	*"We were quite excited to do it [join Enerchain[58]] because we saw that almost all companies are doing it, [...] Same for the EWF. Here, E.ON joined because it was a big consortium and they had an interesting roadmap, but also other big players on board."*- Fabian Grote, E.ON *"The blockchain technology is quite young and it is still being developed. This is why the Energy Web Foundation has an ecosystem of affiliates which includes all stakeholders from transmission and distribution system operators, start-ups, regulators etc. Everyone is coming together and says we know we have this problem, we want to solve this problem, the only way is by coming together and contributing to the development of a technology we all agree on. And if we all agree on it, it becomes easier to change the policy in favour of the implementation of such technologies."*- Fatuma Mohamed, Grid Singularity *"They [large players] join 3 or 4 [solution initiatives] at the same time, they have it run at the same time and at the end then there will be a consolidation and a few will be left."*- Consultant, Big 4 *"Standardization can be achieved through joint action. It needs to have an open architecture, either in consortium or publicly open"*- Fabian Grote, E.ON
4.4.4.	Accelera-tors and in-cubators	*"Green:field is an open innovation platform that brings together people with promising business ideas both within and outside Vattenfall, and helps people put their ideas into practice and integrate them at Vattenfall. The primary goal of green:field is to put business on a level playing field. In contrast to many standard accelerator programs or incubators, individual partnerships and coaching sessions are the main focus.*"- Charlotta Edeland, Vattenfall
4.4.5.	Partnerships	*"We certainly do want to be aligned with our partners and we need to make sure that sort of the interest is the same that they have"*- Scott Kessler, LO3

[58] A consortium for the purpose of enabling blockchain-enabled electricity at the wholesale-level

		"Centrica is very interested in this. They have been very progressive in how they want to progress in the future. These are reasons why we would like to work with them"- Scott Kessler, LO3
		"In collaboration with our partner, what we found out that billing is actually a very important customer touch point. [...] So while it would provide benefits to us and probably make this project easier to do, it ends up being counter to the value that we want to bring to the relationship"- Scott Kessler, LO3
		"We want to grow fast and probably in multiple markets, we need partnerships that help us do that. We don't think we can do that in multiple markets by ourselves."- Scott Kessler, LO3
4.4.6.	Direct interactions with institutional actors	*"We certainly do want to influence [the regulator] that to the extent that we can"*- Scott Kessler, LO3
4.4.7.	Monitoring	*"We will continue monitoring the activity"*- Charlotta Edeland, Vattenfall
		"In that technology scouting, blockchain is in our radar and I have been working for a few years now with blockchain and my task is [...] to keep track of what is happening with this technology"- Alexandra Bådenlid, Fortum

8.8.5. Complementary list of quotes to section 4.5.

Complementary competences and assets in advancing BRET

Section	*Heading*	*Quote*
4.5.1.	Financial resources	*"They [utilities] have the fund to pay for some portion of our time and effort"*- Scott Kessler, LO3
		"Just like any other startup, I think funding is a major component of this. More funding accelerates it, less funding slows things down."- Evan Caron, Swytch
		"Fortum is constantly working with startups through various pilots. One way is through our 150MEUR venture fund Valo venture allowing startups to synergise with some of our generation plants for testing specific use cases."- Ninad Mutatkar, Fortum

4.5.2.	Expertise	*"[Work on microgrids] requires a lot of business developers, civil engineers, electrical engineers, installers and experts in different domains. It is always a collaboration and startups could be part of it but [not alone]"*- Catarina Naucler, Fortum *"[Utilities] have very competent experts, they have the power still, the financial core, the investment"*- Martin Knaack, Microsoft *"We are helping clients to helping start or running pilots in P2P trading."*- Robert, Pöyry
4.5.3.	Ideas and testing of ideas	*"For some of our utility partners, I am running simulations right now with data they provided for different peer to peer energy scenarios and use cases. [...] we need to create and test these use cases in order to improve on our P2P energy trading platform and create more features. This is immensely helpful to our open source project"*- Fatuma, Grid Singularity *"Startups are very relevant for the energy industry because they are able to develop in their own ecosystems, in their own pace, in their own cost structure very fast use cases. They can prep prototypes. And this is what a utility company hasn't done before and the culture is very different. So, it is very good to have these external R&D vehicles for business case innovation or for disruptive innovations."*- Robert Schwarz, Pöyry *"We even try use cases ourselves, we build them, also the technology and we test it."*- Consultant, Big 4
4.5.4.	Customer base and distribution channels	*"If you [as a startup] then go to the utility or relevant incumbent player and do it together with them or get a chance to access their channels, customers or sales, then you have a 100 times larger audience that you can talk to. [...] Startups are dependent on major players. They might not have the solution, but they have the customers"*- Consultant, Big 4 *"Centrica has [...] lots of different communities that would be good candidates. So, we want to start scaling and offer it to many of their communities and not just the one that we start with."*- Scott Kessler, LO3 *"For us, talking to consumers directly would require significant resources. So, actually the Swytch data process is to work through business to business and B2B2C"*- Evan Caron, Swytch

4.5.5.	Ownership of infra-structure	*"This is why we benefit from having a partner because most of the time our partner owns the meter or has certain rights to use it or get data from it."*- Scott Kessler, LO3
4.5.6.	Regulatory compliance	*"They have regulatory license, they have retail license to sell electricity"*- Scott Kessler, LO3
4.5.7.	Influence on the market	*"That depends if you have the utilities or grid operators on board because if you don't have them on board, then it is difficult. But today we mostly see the utilities and they dictate what happens in the market"*- Consultant, Big 4 *"They [utilities] have probably more influence and expertise of the market"*- Scott Kessler, LO3