Juho Leskinen

DESIGN PRINCIPLES FOR BLOCKCHAIN AND SMART CONTRACT SYSTEMS IN THE ENERGY SECTOR: THE CASE OF FINLAND

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF INFORMATION TECHNOLOGY
2021

ABSTRACT

Leskinen, Juho
Design Principles for Blockchain and Smart Contract Systems in the Energy Sector: The Case of Finland
Jyväskylä: University of Jyväskylä, 2020, 100 pp.
Information Systems Science, Master's Thesis
Supervisor: Kazan, Erol

The energy industry in Europe is in the middle of significant changes as the ambitious plans to reduce carbon emissions are setting new requirements for the energy generation. The development of renewable energy sources has been presented as an environmentally friendly solution to this issue, but due to large proportion of renewable energy generation being weather dependent, the volatility in the energy market is increasing. The volatility issues have increased the demand for more flexible energy system that would be more resistant to the rapid changes in energy generation and consumption levels. European Union (EU) have pursued higher level of harmonization between its member states energy legislation in order to move towards pan-European electricity and energy markets. In addition, Nordic countries are reforming their energy markets through the introductions of data hubs, which are centralised information exchange systems for the electricity retail markets. Presented changes are placing considerable challenges for the Finnish energy sector. This Master's Thesis explores how blockchain and smart contract systems could be utilized in the Finnish energy sector, and how they could solve the previously presented issues. Blockchain and smart contract systems are emerging technologies that have already demonstrated their benefits regarding automation, information security and process efficiency. Over the last couple of years, these solutions have had growing interest from the energy industry as different blockchain or smart contract-based solutions have been presented. Different pilot projects utilizing blockchain systems have been implemented around Europe and North America. Many of these pilot projects have presented different kinds of peer-to-peer trading systems utilizing blockchain and smart contract systems. Despite of promising results, the possibilities of the technologies in question have not been largely researched in the context of Finnish energy sector. This research paper presents simplified conceptual model of Peer-to-Peer trading in energy community and analysis discussing strengths, weaknesses, opportunities, and threats of blockchain and smart contract systems in the Finnish energy sector.

Keywords: Blockchain, Smart contract, Energy sector, Peer-to-Peer trading, Energy Community

TIIVISTELMÄ

Leskinen, Juho
Design Principles for Blockchain and Smart Contract Systems in the Energy Sector: The Case of Finland
Jyväskylä: Jyväskylän yliopisto, 2020, 100s.
Tietojärjestelmätiede, Pro gradu -tutkielma
Ohjaaja: Kazan, Erol

Euroopan energiasektori on suurten muutosten keskellä kunnianhimoisten päästövähennystavoitteiden asettaessa uusia vaatimuksia energiatuotannolle. Uusiutuvan energiatuotannon kehitystä on esitetty ympäristöystävällisenä ratkaisuna tähän ongelmaan. Suuri osa uusituvasta tuotannosta on kuitenkin sääriippuvaista, jonka myötä energiamarkkinoiden epävakaus kasvaa niiden tuotanto-osuuden kasvaessa. Nämä ongelmat ovat lisänneet tarvetta joustavammalle energiajärjestelmälle, joka kestäisi paremmin nopeita muutoksia energiantuotannon ja –kulutuksen tasoissa. Euroopan Unionin (EU) tavoitteena on ollut harmonisoida jäsenvaltioidensa energialainsäädäntöjä, jotta Euroopassa voitaisiin siirtyä kohti yleiseurooppalaisia energia- ja sähkömarkkinoita. Lisäksi Pohjoismaat ovat uudistamassa energiamarkkinoitaan ottamalla käyttöön kansallisia data hubeja, jotka ovat sähkön vähittäismarkkinoiden keskitettyjä tiedonvaihtojärjestelmiä. Nämä muutokset aiheuttavat merkittäviä haasteita Suomen energiasektorille. Tämä Pro gradu –tutkielma tutkii kuinka lohkoketjuteknologioihin ja älysopimuksiin perustuvia järjestelmiä voitaisiin hyödyntää Suomen energiamarkkinoilla ja kuinka niiden avulla voitaisiin ratkaista edellä esitettyjä haasteita. Lohkoketju- ja älysopimusjärjestelmät ovat kehittyviä teknologioita, joiden hyödyt automaation, tietoturvan ja prosessitehokkuuden suhteen on demonstroitu aikaisemmissa tutkimuksissa. Viime vuosien aikana energiasektorin kiinnostus näitä teknologioita ja niiden tarjoamia ratkaisuja kohtaan on kasvanut. Pilottiprojektit Euroopassa ja Pohjois-Amerikassa ovat hyödyntäneet lohkoketjuteknologiaa ja älysopimuksia erilaisissa vertaisverkko-projekteissa. Lupaavista tuloksista huolimatta, näiden teknologioiden mahdollisuuksia ei ole laajasti tutkittu Suomen energiamarkkinoiden kontekstissa. Tämä tutkimus esittää yksinkertaistetun mallin energiayhteisölle, joka hyödyntää sisäisessä energiakaupassaan lohkoketjuteknologiaa ja älysopimuksia käyttävää vertaisverkkoa, sekä analyysin kyseisten teknologioiden vahvuuksista, heikkouksista, mahdollisuuksista ja uhkista Suomen energiasektorilla.

Avainsanat: Lohkoketju, Älysopimus, Energiasektori, Vertaisverkko, Energiayhteisö

FIGURES

TABLES

TABLE OF CONTENTS

1 INTRODUCTION

The Finnish energy sector is in transformation. The regulations in the industry are changing, and the introduction of a centralised information exchange system Datahub is reshaping the practices in the energy sector (Fingrid Datahub, 2019). Simultaneously, technology is developing rapidly, and households can produce energy independently (Zhang, Wu, Zhou, Cheng, & Long 2018; Fingrid & TEM, 2018). Besides, the global changes including diminishing natural resources and climate change are forcing the industry to accelerate the implementation of renewable energy sources and to find solutions to improve energy efficiency. These developments are urging the whole energy industry to develop its processes, which means that there is a significant need for technological development as well.

As the attitudes towards consumption have changed drastically in recent years, concerns over sustainability and environmental impact of energy consumption have grown. Concern about climate change and wishing for social embeddedness through localness and communal consumption, have made collaborative consumption, sharing economy and local energy markets an interesting alternative for consumers (Hamari, J., Sjöklint, M., & Ukkonen, A. 2016; Blom, 2018). Changes in attitudes towards energy consumption have laid the foundation to change from the current system where energy supply is centralised, towards distributed renewable energy systems at the community level. (Hamari et al., 2016)

As mentioned above, climate change and global warming could have substantial effects on the energy industry. In the European energy roadmap 2050, European Union (i.e. EU) has committed to reducing greenhouse gas (GHG) emissions at least by 40% of the 1990 levels by 2030 to mitigate the impacts of climate change. The EU has also set a target of 32.5% improvement in energy efficiency by 2030, while the whole union should be carbon neutral by 2050 (European Commission, 2020). Finland has gone even further by pledging to be carbon neutral by 2035 (Henley, 2019; Valtioneuvosto, 2020), which means that the human-induced emissions should not exceed the carbon sinks (Khosravi, Olkkonen, Farsaei & Syri 2020). In practice, this means that Finland has committed to balancing out its carbon emissions by funding an equivalent amount of carbon savings elsewhere. For instance, Finland is abandoning the usage of hard coal by 2029 (Khosravi et al., 2020).

The power and transportation industries are the main contributors of carbon emissions with 30% and 20.3% of the global GHG emissions respectively (Bremdal, Olivella-Rosell, Rajasekharan & Ilieva 2017). The energy industry plays a vital role in these plans as the need for better energy efficiency is rising. Reducing emissions in these industries relies heavily on the deployment of distributed renewable energy in the form of wind, solar power, and the electrification of the transportation industry by transitioning towards electric vehicles. Increasing the production proportion of wind and solar energy will increase the volatility in the market, as the production of energy becomes more weather dependent.

These solutions are affecting major changes in the way power systems, technologies and other systems attached to it are organised. The traditional top-down flow of power supply by large power plants, which cover a major proportion of power demand could be complemented by more integrated models where power and consumption are located on the same grid level (Blom, 2018). However, this kind of development would create a need for significant changes and investments in technology and information systems in the energy sector.

To support a more integrated model where power generation and consumption are located on the same grid level, the infrastructure and information systems in the energy sector need huge development as well. For instance, there is a need in the industry to develop different types of technologies and systems, but we have the open question as to what technologies and how they should be exploited to achieve the aforementioned goals.

One solution is to push for a higher level of automation in the energy market. The basis for this development is already created through solutions like smart meters and smart grids. The data exchange in Finland is also developing as the industry is moving to a centralised exchange of data, through the deployment of the centralised information exchange system Datahub in 2022 (Valtioneuvosto, 2019). The possible introduction of the Nordic Balancing Model with a 15-minute imbalance settlement period might also cause drastic changes in the Finnish energy market. (Nordic Balancing Model, 2020a; Nordic Energy Regulators, 2018)

The aforementioned need for a higher level of automation in the energy sector has created an avenue for new technologies to reorganize the processes in the energy industry. Smart contracts have emerged as one promising solution to perform the automation of processes in the energy market, because of its ability to automate processes based on its fixed rules. Especially, smart contracts and blockchain systems together could provide interesting possibilities for process automation in the energy sector concerning the automation of processes and data storing. (Christidis & Devetsikiotis, 2016)

The history of blockchain and smart contracts is relatively short. In 1991, Haber and Stornetta described the first works that discussed the cryptographically secured chain of blocks (Narayanan, Bonneau, Felten, Miller & Goldfeder, 2016). The first blockchain was conceptualized in 2008 by a person or group of people, known as Satoshi Nakamoto (Staff, 2016), while the concept of smart contract was presented by Nick Szabo in 1994. (Christidis & Devetsikiotis, 2016).

In the last ten years, the interest in understanding blockchains and smart contracts has grown substantially. A large part of these studies discusses blockchain and smart contracts from a general viewpoint, which means few studies are looking into specific industries and how blockchain and smart contracts could be applied. However, there is considerable interest in the energy sector industry in how blockchain and smart contract systems could be utilized.

As such, this thesis aims to explore how blockchain and smart contract systems could be utilized in the energy industry. In so doing, this thesis adopts the Finnish energy provider sector context. This is a worthwhile research topic, because the energy industry could benefit from smart contracts and because there is an on-going Datahub-project to create a centralised information exchange system for the Finnish electricity retail market. (Fingrid Datahub Oy, 2019).

Automated systems utilizing smart contracts could be an interesting development for the industry from the perspective of energy efficiency. Currently, the markets are not intensively guiding consumers regarding their energy consumption. High-level energy system automation including the processes of energy trading and consumption could guide the consumers to use energy more evenly, which would reduce the consumption during peak demand periods. This kind of development would increase the resilience of the energy system as it would automatically balance the consumption levels in accordance with the energy generation levels. (Kumpulainen et al., 2016)

Automated processes would also be an interesting option from the perspective of electricity trading especially concerning the introduction of a 15-minute imbalance settlement period. Currently, the imbalance settlement period is one hour, which is why the existing electricity trading systems lack the ability to react in real-time to the substantial amount of precarious renewable energy (Monacchi & Elmenreich, 2016; Khodadadi et al., 2020). The replacement of conventional power generation with renewable energy sources raises concerns regarding the loss of load probability (Tómasson & Söder, 2020; Khodadadi et al., 2020).

As the imbalance settlement periods are becoming shorter and the amount of transactions is increasing, the delays caused by manually managed operations are increasing. Electricity wholesale market and sales processes could work much more efficiently with automated processes utilizing blockchain and smart contract systems. Overall, blockchain and smart contract systems have many utilization possibilities in the energy sector.

1.1 Research question

The overall research questions for this study is:

- How can blockchain and smart contract systems be used in the energy sector?

This is supported by sub research questions, which are:

- What are blockchain and smart contract systems?
- How are energy providers currently managing contracts?
- What are the business and technology requirements for blockchain and smart contract systems in the Finnish energy market?

The main goal of this thesis is to study how blockchain and smart contract systems can be utilized in the Finnish energy sector.

1.2 Scope and structure of thesis

The literature review of this study contains definitions and descriptions for blockchain and smart contracts, and how they can be utilized. Furthermore, descriptions about the Finnish energy sector, how energy businesses are working in Finland and the ongoing Datahub project are included to the literature review. The concept of smart grid is also described and specified. Research databases like Google Scholar as well as industry specific databases like IEEE are utilized to identify relevant studies. Reports published by governmental bodies were used as references for this study as well.

In addition, primary data has been collected in the form of semi-structured expert interviews. The interview partners work in the Finnish energy sector and are knowledgeable about blockchain technology and smart contracts.

The results should of this study should help to understand how smart contracts could be utilized in the Finnish energy sector while at the same time identifying the needs for different stakeholders. By having a better understanding of how the energy industry, its infrastructure could leverage on smart contracts, it would create future avenues for more research, and more importantly, foster its practical application in Finland, which supports Finland's ambitions in becoming carbon neutral.

2 LITERATURE REVIEW

This chapter is demonstrating the background of the research by presenting the current state of the energy industry and the technologies of blockchain and smart contract systems based on earlier research made regarding these subjects. The first subchapter is presenting the current state of the energy markets in Europe, Nordic countries, and Finland. The second subchapter is presenting the concept of smart grids including its demonstrated possibilities. The third chapter is demonstrating the concepts of blockchain technology and smart contracts and discussing the utilization possibilities of them in the energy sector including existing concepts from pilot projects, and technological and legal requirements. The fourth chapter is summarizing the content of the literature review. The terms specific to energy sector are explained in table 1.

2.1 Energy sector

The energy sector in Europe and North America has been restructured since the 1990s. The introduction of wholesale and retail markets has increased competition and therefore, the market design of the electricity sector has become more complex (Fridolfsson & Tangerås, 2009). In the last few years, climate change policies have heavily incentivized the deployment of renewable energy sources. (Orlov, 2017; Bocquillon & Maltby, 2017; Child, Kemfert, Bogdanov & Breyer, 2019).

The present energy system will face various challenges in the near future because of changing demand and production structures. The rapidly increasing amount of renewable energy production is causing intermittency issues for the energy and power balance as the proportion of weather-dependent energy production is increasing. As a result, the volatility in the energy market is increasing and raising the need for regulating power from present and new energy resources. The consumption structure is also changing through factors introductions of energy-efficient houses, heat pumps, and electric vehicles. The changes that the energy system is going to face are both a technical and business nature. (Tikka et al., 2019; Tuunanen, 2015)

Renewable energy sources have not been the only ground-breaking change in the energy retail market in recent years, as the development of information and communication technologies (ICT) has affected the industry as well by changing the nature of living and doing business (Mourshed et al., 2015).

According to Orlov (2017), the electricity grids are largely based on technology from the first half of the 20th century, which means that ICT could enable substantial upgrades for the old grid infrastructure through development enabling new solutions for electricity trading and grid control. This upgrade could be vital in order to accommodate the changing nature of the power system due to renewable energy sources and to promote opportunities for grid control and electricity trading.

Newer technologies are also raising expectations for the so-called energy internet (Zhou, Yang & Shao, 2016), which means that highly interconnected and distributed energy network becomes part of the Internet of Things (IoT). Higher efficiency, the security of supply, and the breakage of the historically monopolistic ownership structure could be the outcomes of this possible development. (Orlov, 2017)

TABLE 1 Terms in the energy sector

Term	Explanation
Distribution system operator (DSO)	Operating managers, and in some cases owners of energy distribution networks, operating at low, medium and in some cases high voltages. (Edso, 2020)
Transmission system operator (TSO)	Organisation that is committed to transporting energy in the form of electrical power or natural gas on a national or in some cases regional level, exploiting fixed infrastructure (EntsoE Event, 2020)
Grid companies	Distribution system operators and Transmission system operators. (Edso, 2020; EntsoE Event, 2020)
Liberalised electricity markets	Markets where consumers able to freely choose the electricity retailer and services. (Olsen, Johnsen & Lewis, 2006)
Electricity wholesale markets	Markets where electricity is traded (purchased and sold) before it is delivered to end consumers (individuals, households, or businesses) through the grid. (CRE, 2019)
Intraday market	The wholesale market for continuous buying and selling of energy at the energy exchange that takes place on the same day as the power delivery. (Maciejowska, Nitka & Weron, 2019)
Electricity balancing market	Market that establishes market-based balance management in an unbundled electricity market. The platform, where TSOs settle any deviations remaining after the closure of intraday markets. (van der Veen & Hakvoort, 2016)
Retail competition model	Open access to all wires, including high-voltage (transmission) and low-voltage (distribution). This model separates the provision of wires from power service. (Beato & Fuente, 1999)
Electricity retail company	Companies that sell electricity to final customers. (Beato & Fuente, 1999)
Datahub	Centralised information exchange system for the Finnish electricity retail market. (Fingrid Datahub, 2019)
Imbalance settlement	Determines the electricity deliveries between the participants operating in the electricity market. The process is based on the hierarchic imbalance settlement model (Figure 7) and chains of open deliveries. (Fingrid, 2020a)
Imbalance settlement period (ISP)	The time unit for which the imbalance of the balance responsible parties is calculated. (European Commission, 2017)
Guarantees of origin	Certifying the green value of renewable energy. (Klessmann, Ensslin & Ragwitz, 2007)

2.1.1 European energy market

Peng & Boudineh (2019) argued that the increase of renewable energy sources is reshaping the European energy industry, as by 2030, the proportion of renewable energy generation is expected to account for up to 50 percent of the EU's overall power supply. The energy sector is at the centre of EU's ambitious decarbonisation policies, which have significant implications for the energy systems and electricity systems in general. (Peng & Boudineh, 2019)

Erbach (2016) explained that the ultimate objective of the EU's energy legislation is to achieve an increasingly interconnected European electricity market with convergent prices across the union. The electricity markets in the EU operate on various levels. Wholesale markets are organised differently than retail markets, which provide electricity for consumers. The markets vary in geographical scope as they range from transnational wholesale markets to local offers on the retail market. (Erbach, 2016)

In a liberalised market, which is used in Nordic countries, for instance, there are different responsible parties for generating electricity, operating the transmission system (transmission system operators, TSO), and the distribution system (distribution system operators, DSO). These operators are required to provide third-party access to their networks (Erbach, 2016). The flow of electricity from production to consumption is presented in Figure 1.

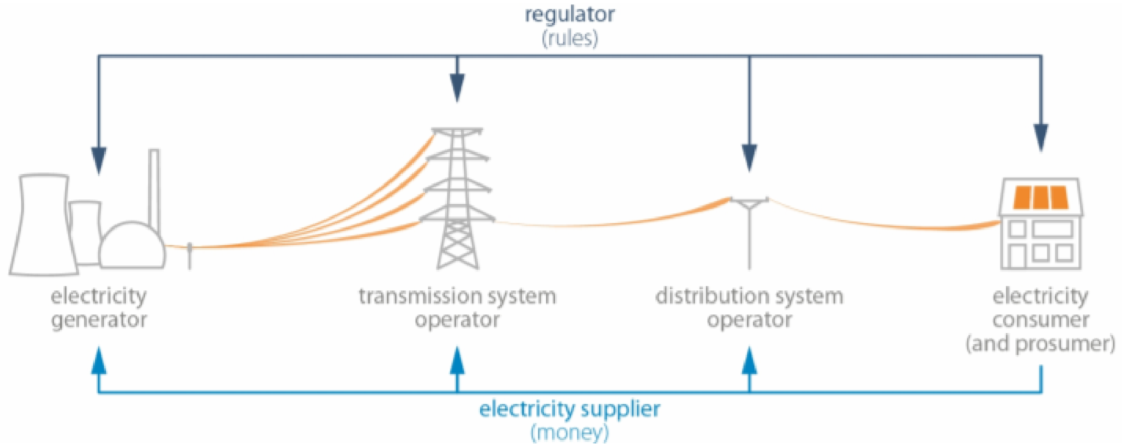

FIGURE 1 Schematic overview of the electricity system (Erbach, 2016, pp. 3).

According to Erbach (2016), these third parties are usually suppliers (Retail companies) in the electricity retail market, who offer electricity contracts that are approved by the competent regulator. Suppliers buy electricity from electricity wholesale markets and sell it to consumers, who have the right to choose their supplier. Suppliers send invoices for the delivered electrical energy. In some cases, they also send invoices for transmission and distribution. (Erbach, 2016.) However, in Finland for instance, DSO companies might send a separate invoice for the transmission of electricity (Pahkala, Uimonen & Väre, 2018). The practicalities of invoicing vary between companies and countries.

The introduction of European intraday markets in June 2018 enabled more extensive European electricity markets for continuous trading. The Cross-Border Intraday (XBID) project created the marketplace for continuous trading in Europe. The joint market includes Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, the Netherlands, Norway, Portugal, Spain, and Sweden, for instance. (Fingrid, 2018). However, Ocker and Jaenisch (2020) are arguing that intraday trading should be revised and developed in a manner that the integration of volatile renewable energy sources in the system is facilitated utilizing all appropriate means of market design. Presented issues concerning current market designs are raising questions towards the future developments in the industry.

Considering future developments of the European energy sector, Battaglini, Lilliestam, Haas, & Pat (2009) presented an approach that combines decentralised Smartgrid with centralised grid to produce a vision for Smart Grid. They argued that the concepts are mandatory and must co-exist to guarantee the desired transition to a decarbonised economy. According to Child, Kemfert, Bogdanov & Breyer (2019), their vision is consistent with the idea that Europe already has areas where energy cooperation is implemented. These regional partnerships the potential to deliver an expense-optimised implementation of smart grids, renewable energy sources, and energy efficiency. (Battaglini et al., 2009; Child et al., 2019)

EU's ambition towards more harmonized markets is affecting Finnish and Nordic energy markets and the energy industry in general as well. The changes in processes and practicalities are on the dimension of the changes, as the expanding wholesale markets are reshaping the competitive situation in the markets.

2.1.2 Nordic energy market

Ma, Prljaca & Jørgensen (2016) stated that the Nordic electricity market is one of the best examples in the world concerning the international electricity market due to its highly integrated and highly balanced mechanisms to arrange cross-country trade. Since 2001, there have been no transmission charges for cross-border trade among the Nordic countries (Ma et al., 2016), which is showing how interconnected Nordic countries' electricity markets are with each other. Even though this study is not focusing on international electricity markets, the common Nordic electricity markets also urge to concentrate on what is happening in other Nordic countries and how these developments are affecting the national electricity markets.

According to Olsen et al., (2006), the Nordic countries are using a liberalised energy market, where consumers have two contracts while being supplied with electricity, the distribution contract, and a supply contract. Figure 2 illustrates the different electricity market models. Model I is illustrating the market model that is commonly used in the Nordic countries (Olsen et al. 2006). Previously consumers only had one contract with the company that was managing the distribution system. The distribution contracts are concerning all distribution and metering issues, while the supply contract concerns the electricity commodity itself. The supply contracts are regulating the relationships between consumers and suppliers/retailers. (Olsen, Johnsen, & Lewis, 2006; Ma et al., 2016.)

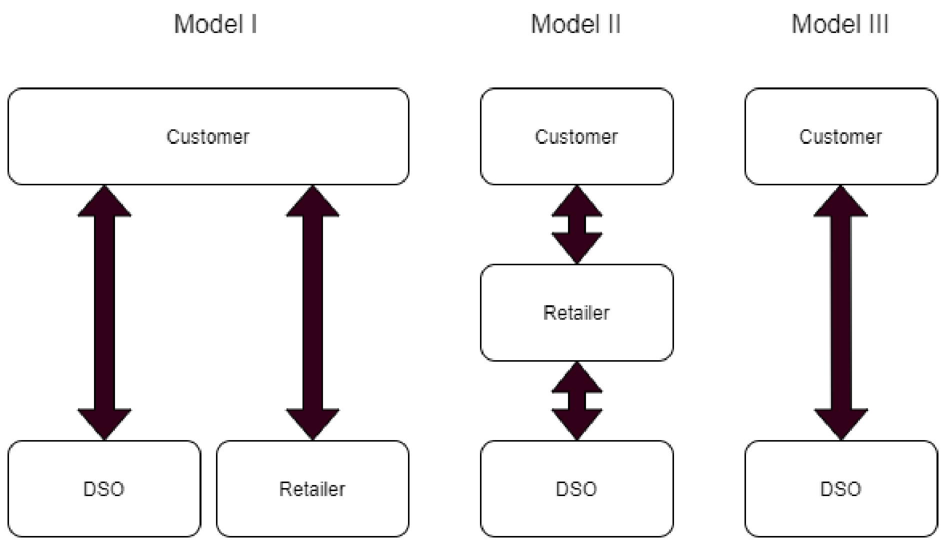

FIGURE 2 Different electricity market models

Ma et al. (2016) argued that the liberalised electricity retail market has also increased the demand for data exchange. Previously, consumers only had one relationship with their electricity distribution company, which was responsible for retail and transportation of electricity. The market liberalisation transformed the markets as distribution companies were separated into electricity retailers and grid companies. The complexity of the electricity market structure increased as a result and increased the demand for data exchange in the process. (Ma et al. 2016)

Denmark introduced Datahub to simplify the data exchange among parties in the electricity market. All the electricity data exchange is happening through the Datahub. In their system, the grid companies are responsible for the master data collection from all the metering points and reporting the gathered master data to the Datahub. It has become an instrument in the liberalized market, and it can be seen as the preparation for the future electricity market. (Ma et al. 2016)

Other Nordic countries are also developing similar projects. Norway introduced Elhub in 2019 (Østli, 2019), while Sweden and Finland plan to deploy their data hubs in the coming years. (Svenska Kraftnät, 2019; Ediel, 2020) Besides, Nordic countries are harmonizing a part of their markets by introducing a common balancing model (Nordic Balancing Model, 2020a).

The current wholesale power markets can ascertain the planned balance of supply and demand, but they cannot ensure the operational security of the power system in real-time. Responsibility of balancing has been the task for transmission system operator (TSO), which is balancing consumption and power generation at every instant. The current balancing model used in the Nordic countries is based on controlling the frequency in real-time. (Khodadadi et al., 2020)

However, Khodadadi et al. (2020) argued that recently the frequency is increasingly falling outside the limits. Besides, the current balancing model lacks the perquisites for taking advantage of the ongoing process of harmonizing the European balancing area. Modernizing the balancing model could bring versatile balancing markets to the Nordic region while enabling cost-efficient use of resources in the region by increasing the trading of flexible resources with other European countries. (Khodadadi et al., 2020) In order to pursue this, the Nordic countries have accepted a joint roadmap for implementing the new balancing concept and a joint balancing market (Fingrid, 2018).

The program is called Nordic Balancing Model and its purpose is to develop the Nordic Balancing Market design, the operational processes, and the associated operational methodologies. The goal is to meet the outlined target model agreed in the Cooperation Agreement and necessitated in the European legislation. (Nordic Balancing Model, 2020b) The Nordic countries plan to implement the 15-minute imbalance settlement period at the same time with each other. (Nordic Balancing Model, 2020a)

As described in Fingridlehti (2018), while the amount of renewable energy sources is growing, the level of weather-dependent energy generation is growing as well. Currently, the imbalance settlement period is one hour, which means that the prices for electricity trading are set by the hour. Transforming into a 15-minute imbalance settlement period is helping the energy suppliers to meet the need for more flexible consumption in the future, which is caused by the energy transformation and the increased amount of inflexible and weather dependent production. (Fingridlehti, 2018)

A shorter imbalance settlement period is setting a more accurate value on the price of energy, which can encourage investments in new technology, like consumption flexibility. With shorter imbalance settlement periods, the imbalance deviations are set more accurately, and costs are directed more correctly, which can offer incentives to market participants to manage their imbalance more closely. Participants receive rewards from flexibility and price signals offer possibilities for adjustable production and consumption to achieve monetary benefits (Fingrid, 2020b). A Shorter imbalance settlement period can also lower the threshold to participate in the intraday and electricity balancing market and enable better integration between different European electricity markets. It could also improve the power systems level of operational reliability. (Fingridlehti, 2018)

2.1.3 Finnish energy market

Jääskeläinen (2019) argued that even though Finland is a small country, it has a relatively high demand for energy due to the cold climate and energy-intensive industry. Simultaneously, Finland is one of the forerunners in the implementation of renewable energy sources with the second-highest share of them in the EU after Sweden (Cross et al., 2015). From an electricity production perspective, Finland produced 47% of all generation with renewable energy sources in 2018. Hydropower and wood-based fuels contributed together 19%, while wind power contributed 9%, and solar power 0.2% of all electricity generation in 2019 (Khosravi et al., 2020; Finnish Energy, 2019).

Currently, the Finnish electricity retail market is going through significant changes. The deployment of Datahub in 2022 (Fingrid, 2020c) will move all retail market communication from a decentralised model to a centralised information exchange system. Connected to the Datahub projects in Finland and Sweden is the possible introduction of the 15-minute imbalance settlement period. Besides, there are efforts to converge or harmonize the electricity market communication between the member states of the EU (Hiekka, 2019). These changes are naturally affecting Finland's internal markets as well.

In Finland, the issue of generation adequacy during the demand peaks in winter has been a talking point in the political discourse and media. Even though it is declared that the Finnish energy system has enough generation capacity and intervention actions to cope with unexpected faults (Jääskeläinen, Zakeri & Syri, 2017), several simultaneous market trends are increasing the stress regarding the security of supply. These trends are the increasing share of weather-dependent power production, prolonged low level of electricity market price, and the decreasing number of installed thermal power plants (Jääskeläinen et al. 2018). As a counterbalance to the increasing amount of weather-dependent production, electricity grids are becoming more weatherproof in Finland (Energiateollisuus, 2016). This ongoing change is illustrated in figure 3.

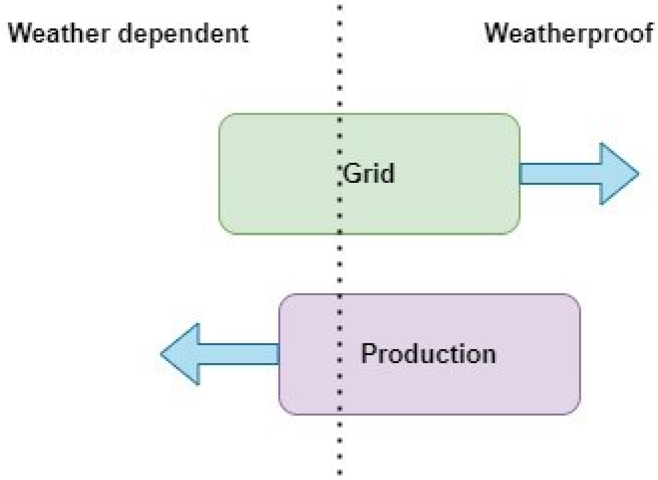

FIGURE 3 Grids becoming more weatherproof and energy production becoming more weather dependent.

According to Jääskeläinen et al. (2018), Finland is more and more dependent on cross-border electricity trade. In 2016, 22.3% of the total electricity consumption in Finland was covered by net electricity imports, which were largely imported from Sweden (Jääskeläinen et al., 2018). The Nordic countries are progressing towards the harmonized market model. The data hub projects will be an essential step in this process, as these new systems are improving supplier-centric switching and updating the processes for switching suppliers once they are established. (Nordic Council of Ministers, 2017)

One of the biggest changes in the Finnish energy industry is happening in 2022 through the deployment of Datahub (Fingrid, 2020c). After the deployment, when a Finnish consumer changes electricity supplier, all the necessary information between the seller of electricity and distribution network company will be sent through the centralised information exchange system, which is known as

Datahub. The change is substantial because currently, the data is in various companies' systems. (Ediel, 2020)

As all the essential electricity use information is centralised in one place, the Datahub is going to speed up, simplify, and improve the actions of all parties. The solution will also provide all parties with equal and simultaneous access to the information. Datahub is also able to process and redefine information saved in it. (Ediel, 2020)

The Datahub together with smart systems is also enabling consumers in participating in demand-side management, which means balancing electricity production and consumption in a manner that the use of electricity will automatically be adjusted to the load of the grid. Electrical appliances can be switched off during load peaks, while excess production can be led to large building systems, for instance. (Ediel, 2020)

Even though the Finnish energy market has big challenges, it also has a large scale of opportunities. Smart and remotely read electricity meters are broadly used in Finland, and a lot of information is gathered from these meters on daily basis (Ediel, 2020). The deployment of smart applications has created readiness for the Finnish energy market to adapt to new systems.

Long and cold winters, moving to renewable energy sources, cross-border trade, demand for higher energy efficiency, and possible change to a 15-minute imbalance settlement period are causing challenges for the industry in Finland. These challenges could be solved by blockchain and smart contract systems.

2.2 Smart grid

Definitions for smart grid environments are diverse (Farhangi, 2009; Clastres, 2011). In principle, a smart grid is required to provide pervasive control over the DSO's (Distribution System Operator) services and assets. Expanding control and monitoring options in the smart grid solutions will necessitate convergence of information and communication technologies in the energy systems. Thus, investments in electricity distribution automation are going to enable improvements to capabilities in the future with the role of communication and data management intensifying. (Tuunanen, 2015; Farhangi 2009)

Smart grid technology is introducing two-way communication between utility companies and their customers. This is enabling better integration of the newer energy generation technologies, like solar and wind energy. The smart grid is strongly linked to smart homes, which are communicating with the grid by logging and sending data to the smart grid through a smart meter, which is enabling consumers to manage their electricity consumption more efficiently (Kabalci, 2016; Zheng, Gao & Lin, 2013; Hao et al. 2013).

Measuring homes' electricity levels more efficiently mean that utility companies are able to provide better information to their customers, which is enabling them to manage their energy consumption and how much they are paying for the service. (Gao et al. 2018)

Gungor et al. (2011) have described the problems concerning today's power distribution systems. Poor visibility, mechanical switches causing slow response times, and a lack of automated analysis, and situational awareness were some of the deficiencies found in their study about current power distribution systems. They suggested that the smart grid would address these problems. Several communication technologies associated with the smart grid were also mentioned in the study. (Gao et al. 2018)

Järventausta, Verho, Partanen & Kronman (2011) explained that the concept of smart grid introduces new solutions like power electronics and direct current systems, which can be utilized in the future for power distribution infrastructure. The traditional and passive distribution network will be reorganised to an active system that included a distributed generation of energy and energy storages. In addition, new ICT solutions for asset management and network operation should be able to provide intelligence for active networks. (Järventausta et al., 2011)

According to Järventausta et al. (2011), automation and ICT systems are currently at the centre of network operation. Their role will grow as the development of smart grids raises the demands and opportunities concerning the low voltage network automation. Distributed generation, charging of electric vehicles, and advanced metering infrastructure are examples where low voltage network automation can be implemented. The amount of data and the number of information systems is growing as well, which means that new data can be integrated into different data systems. For example, automatic meter reading (AMR) systems can be utilized for many functions of the DSO, like network operations and planning, for instance. New software applications and communication interfaces will be a key element of smart grids. (Järventausta et al., 2011)

According to Tikka et al., (2019), the role of microgrids, aggregators (virtual power plants), and energy communities are emphasized in the future the electrical system because they are offering new kinds of flexibility to the energy system. For instance, smart metering systems could enable avenues for consumers to offer flexibility and receive rewards for it (Repo et al., 2020). However, these systems also present new challenges for the management of energy systems. (Tikka et al., 2019)

Intelligent energy solutions possess enormous business potential, but there still are substantial obstacles, which are blocking most of the novel business opportunities in the present system. The lack of an easily accessible and widely accepted interoperable information exchange interface that meets the business needs of all parties involved in the system is one of the biggest obstacles in the current system. (Tikka et al. 2019)

Different kinds of smart grid solutions have been introduced in recent years. Tikka et al. (2019) presented their model of smart grid, which was based on the smart API open-source library working as the common interface for all the resources interacting with their platform. The development of their study should be tracked as its effects could cause changes in the Finnish energy sector in general. However, this paper is focusing on studies discussing blockchain and smart contract technology.

2.3 Blockchain and smart contract systems

In 2011, Gungor et al. stated that poor visibility, mechanical switches causing slow response times, and a lack of automated analysis and situational awareness were some of the major deficiencies in the current power distribution systems. They suggested that the smart grid would address these problems. Since 2011, blockchain and smart contract systems have emerged as an interesting opportunity for energy business and smart grids.

The interest in blockchain and smart contract systems has grown in recent years in the energy industry and different kinds of ideas and concepts have been presented. For example, Mylrea and Gourisetti (2017) proposed that blockchain would increase the resilience of a smart grid. Their model uses blockchain and smart contracts as intermediaries between the consumers and electricity producers.

2.3.1 Blockchain

Blockchain is expected to revolutionize industry and commerce while driving economic change on a global scale. The basis for this change lies in blockchains nature, which has been described as immutable and transparent. Blockchain is also redefining trust by enabling secure, trustworthy, and transparent solutions, which may be private or public. According to Underwood (2016), blockchain could empower people in developing countries with recognized identity, asset ownership, and financial inclusion. It could possibly also support effective healthcare programs and improve supply chains. One of the most interesting areas blockchain could revolutionize is the energy business.

In short, blockchain could be described as a multifaceted, network-based software connector, which is providing communication, coordination, and services for facilitation (Xu et al., 2016). The technology behind blockchains is based on a distributed ledger structure and consensus process. The structure is allowing a digital ledger of transactions to be created and shared between computers on a network. (Underwood, 2016)

According to Kim, Park & Ryou (2018) blockchain is divided into private and public blockchains according to the characteristic of the participant. Anyone can create and read the public blockchain. As a result, it can take a long time to share the blocks on the Internet. It should also be noted that when many blocks are created at the same time, it is difficult to select one specific block so that the block generation is limited. In comparison, the private blockchain can only create blocks for authorized users, and the validation of transactions is only available to authorized users. As a result, network expansion and speed of service are fast. (Kim et al., 2018)

According to Underwood (2016) when a user wants to add a transaction to the ledger, the data is encrypted and other computers on the same network exploiting cryptographic algorithms verify it. Consensus between the majority of computers must be reached before a transaction can be validated and a new block of data can be added to the chain and be shared by everyone on the network. Transactions are described as trusted, secure, immutable, and auditable. They are also avoiding the need for third-party intervention and remediation. (Underwood, 2016)

Christidis and Devetsikiotis (2016) are describing blockchains as logs, which records are batched into time-stamped blocks (Figure 3). Their own cryptographic hash identifies each of these blocks and each of them references the hash of the block that came before it. This is establishing a link between the blocks and creating a chain of blocks, or blockchain. Any node that has access to this list of blocks, can read it and figure out what is the state of the data, which is being exchanged through the network. (Christidis & Devetsikiotis, 2016)

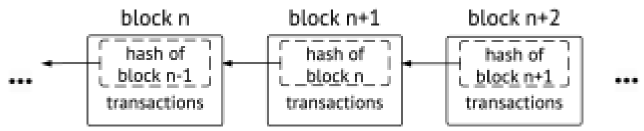

FIGURE 4 Blockchain illustrated. (Christidis & Devetsikiotis, 2016, pp. 2293)

In proportion, Xu et al. (2016) are describing blockchains data structure as a time-stamped list of blocks, which records and aggregates data about the transactions which have ever occurred in the blockchain network. They are stating that blockchain is providing immutable data storage, which only allows inserting transactions without updating or deleting existing transactions on the blockchain in order to prevent revision and tampering. In their description, the whole blockchain network needs to reach consensus before a transaction can be included in the immutable data storage. (Xu et al., 2016)

Blockchains' ability to create, transfer, and store digital assets in a distributed, decentralised, and tamper-proof way can offer large practical value for IoT systems. Micro-payments could be the most obvious use of blockchain technology in IoT, but Samaniego & Deters (2016) consider the storing and sharing of data and code being the most useful at the current state of IoT deployments. This can be seen as a refreshing point of view regarding blockchain from the perspective of the energy industry.

In their paper Kim et al., (2018) presented more specifically how public and/or private blockchain, or in their case Ethereum specifically, can be used in the energy business. They argued that with the private blockchain, people that can produce electricity using solar panels are forming the blockchain. According to them, the protocol can be changed through the agreement of the members, which means it is possible to update it periodically.

According to Kim et al., (2018) the public blockchain platform is allowing anyone to browse trade and verify blocks. Even those who are not directly involved are slowing the transaction processes, as they must validate and archive transactions. Consumers who are also producing energy are called prosumers (Producer/Consumer), and they also need to update the smart meters routinely, but there still lies many problems caused by the block verification and generation speed. Anyone can create a public blockchain, and it can be read by anyone. Therefore, it can take a while to share the blocks on the internet. Because of these reasons, public blockchain is not effective in direct transactions with consumers and prosumers. However, blockchain-based digital ledgers can be used for many purposes, like publicly exchange or store coins, which can be in contracts using a public blockchain. (Kim et al., 2018; Mylrea & Gourisetti, 2017)

The technology behind blockchain has many times been described in general as unhackable (Orcutt, 2019), which has made it so appealing for many industries, like finance for instance. The security of blockchain has also been described as one of the main benefits of it regarding its possible introduction to the energy market.

However, recent incidents have shown that blockchain has its own weaknesses in terms of security. These incidents have occurred around cryptocurrency exchange processes as hackers have stolen nearly $2 billion worth of cryptocurrency. Incidents like these might reduce the trust towards blockchain technology. This matter should be recognized while studying the possibilities technology itself provides for the industry and business. (Orcutt, 2019)

Blockchain systems are facing other challenges as well, especially in the energy sector for start, the policies and regulations regarding blockchain systems need to be in place to help determine to license on other key roles for energy companies. For instance, the schedules and the forecasts of consumptions still need to be submitted to the transmission operator. Another challenge lies with incorporating individual users into balancing groups that are responsible for complying with requirements and submitting accurate demand forecasts to the network operator. (Mylrea & Gourisetti, 2017) The question is how these operations are managed if blockchain-based systems are introduced to the electricity market.

The management of the balancing group is a significant task, and it could potentially increase costs related to blockchain management. In order to avoid these kinds of costly disruptions, the autonomous data exchanges, like demand forecasts from consumers to transmission system operators need to be stress-tested for reliability and security before the solutions are ready for implementation on a large scale. (Mylrea & Gourisetti, 2017)

As previous chapters are showing, blockchain can be described in many different ways and words, from many different angles, and with many different kinds of motives. However, the main question in this research is how blockchain and smart contract systems could be utilized in the Finnish energy sector. Therefore, the opportunities blockchain offers and the risks it contains should be discussed in the paper.

2.3.2 Smart contracts

Contracts, transactions, and records are one of the defining structures of our legal, economic, and political systems. They are protecting assets and set organizational boundaries. They are establishing and verifying identities and governing interactions among nations, organizations, and individuals. They are also guiding social and managerial action. (Raskin, 2016)

Concerning these aspects, it is interesting that the critical tools and the bureaucracies formed to manage them have not kept with the economy's digital transformation. Especially, when a large number of people believe that the private enforcement of contracts could reduce the need and extend of police and legal services arranged by the administrations. (Raskin, 2016) Smart contracts could modernize the management of legal agreements in many industries.

The concept of smart contract was described in 1994 by Nick Szabo as "a computerized transaction protocol that executes the terms of a contract" (Christidis & Devetsikiotis, 2016). Szabo declared that translating contract clauses into code and embedding them into a property that is able to self-enforce them (Szabo, 1997), to minimize the need for trusted intermediaries working between the transacting parties. Raskin (2016) simplified the concept by describing a smart contract as an agreement in which execution is automated. The automatic execution is usually affected through a computer, which is running code that has translated the legal prose into a program that can be executed.

According to Raskin (2016), the essential aspect of smart contracts is that they do not upend the existing social order. Instead, they decrease transaction costs by cutting intermediaries from the transaction process. This is allowing the industries to operate more effectively. Benefits are extending to financial transactions, financial products, corporate governance, and other potential applications, like the energy industry. Raskin (2016) is stating that the smart contract does not rely on the state for enforcement, but it is a way for contracting parties secure performance.

In the blockchain context, smart contracts are scripts, which are stored on the blockchain. Because smart contracts reside on the blockchain, they also have a unique address. A smart contract can be triggered by assigning a transaction to it. As a result, it executes automatically and independently in a prescribed manner on every node in the network, following the data that was part of the triggering transaction. (Christidis & Devetsikiotis, 2016)

Raskin (2016) is describing the two technological components that have enabled smart contracts. The first of these components is called contract ware, which is referring to the physical or digital instantiations of contract terms into machines or other property which is the part involved in the performance of the contract. The second component is called decentralised ledgers, which are also known as blockchains. According to Raskin, these are databases of information, which have been created by a network that has no central authority. (Raskin, 2016)

Smart contracts are operating as autonomous actors, which behaviour is completely predictable. Because of this, they can be trusted to carry forward any on-chain logic, which can be expressed as a function of on-chain data inputs. The simplest example of a smart contract is that it calls another contract by address to execute its main function. The contract is also carrying a list of members, addresses that are able to vote on its behaviour. (Christidis & Devetsikiotis, 2016)

Raskin (2016) is dividing smart contracts into two different slots, weak smart contracts, and strong smart contracts. The latter ones have prohibitive costs of renovation and modification, whilst weak smart contracts do not. In practice, this means that, if a court can alter a contract after it is executed, then it will be defined as a weak smart contract. If the cost for altering is so large that it would not make sense for the court to pursue it, then the contract is defined as a strong smart contract.

The main difference between a non-smart contract and a smart contract is that the parties can stop the performance of the non-smart contract voluntarily or by court order. As the opposite, once a strong smart contract initiates, it must execute. (Raskin, 2016)

Smart contracts could be utilized in the Finnish energy sector. The Datahub project is creating a centralised information exchange system for the whole Finnish electricity retail market. This is an interesting matter from the perspective of blockchain and smart contracts as it could enable the deployment of them in the Finnish electricity market in the future. Concerning this possible development, it is also important to describe the concept of smart grids (Fingrid Datahub Oy, 2019; Blom, 2018; Rahimi & Ipakchi, 2010)

2.3.3 Blockchain and smart contract systems in the Energy Sector

According to Buterin (2014); Delmolino, Arnett, Kosba, Miller, & Shi (2016) and Kosba, Miller, Shi, Wen & Papamanthou (2016) blockchain based smart contracts are presenting an opportunity to increase the scale, security, and speed of energy applications. These opportunities and benefits are interesting from the perspective of energy business, especially when you combine these thoughts with the technology-based opportunities presented earlier in this paper. (Christidis & Devetsikiotis, 2016).

Mylrea and Gourisetti (2017) created a more concrete example about the possibilities of blockchain. In their model, whenever a transaction happens, there is a blockchain-based meter, which is updating the blockchain by creating a unique timestamp block in order to verify the block in a distributed ledger. At the distribution level, the system operators are invoicing the customers based on the data that is recorded to the blockchain.

This development of technology and blockchain systems can provide more resilient path for a decentralised modern grid and integration of internet connected Energy Internet of Things (EIoT) and grid edge devices. Improvements in energy grids optimization and resilience are essential operations and design criteria when the power grids are modernized. (Mylrea & Gourisetti, 2017)

Even though Gao et al. (2018) are seeing smart contracts mostly as a way to identify malicious usage of electrical power and electrical data and to report about these kind of actions into a database, their research is still combining blockchain systems, smart contracts and smart grids in an interesting manner. They are describing sovereign blockchain as technology that has attractive characteristics like immutability, non-repudiation, and decentralization. (Gao et al. 2018)

Mylrea & Gourisetti (2017) described several potential security and optimization benefits that blockchain is presenting to the electricity infrastructure. From the perspective of security, they claimed that blockchain could enhance the trustworthiness and integrity of transactive data by supporting multifactor verification through a distributed ledger. They also claimed that it could provide autonomous detection of data anomalies and real-time responses to unauthorized attempts to alter critical data, applications, configurations and sensor infrastructure and network appliance.

Additional benefits of blockchain were also presented in the paper written by Mylrea & Gourisetti (2017). These benefits included: 1) Enhancement of trustworthiness and preservation of the data integrity; 2) Support for the multifactor verification through a distributed ledger; 3) Securing transaction data integrity; 4) Reducing costs of energy exchanges by removing intermediaries; 5) Facilitating monetization and adoption of distributed energy resource (DER) transactions; 6) Facilitating consumer level exchange of excess generation from DERs and EVs utilizing blockchain based smart contracts; 7) Additional storage and help balancing substation from bulk energy systems; 8) Enabling a more secure distributed escrow in order to maintain ordered time stamped data blocks, which can't be retroactively modified; 9) Quick perception of anomalies in data, which could improve the ability to detect and respond to possible cyber-attacks; 10) Help to align currently diverged blockchain initiatives and facilitate deployment of technology through secure applications; 11) Potential reducing of transaction costs in the energy market; 12) Operators of distribution systems are able to leverage the blockchain to receive transaction data, which is required to invoice network costs from the consumers; 13) Operators of transmission systems could have reduced data requirements and constraints for clearing purposes.

2.3.4 Peer-to-Peer Trading System

One of the possibilities new technology is providing for the energy sector is the Peer-to-Peer (P2P) energy trading, which is a term for direct energy trading among consumers and prosumers. It is usually implemented within a local electricity distribution system. A peer in the P2P energy trading system is referring to one or a group of local energy customers, including consumers, prosumers, and generations. The peers are buying and selling energy directly with each other without the intermediation of other parties, like conventional energy suppliers. P2P trading system is commonly enabled by ICT -based online services. (Zhang et al. 2018; Hamari et al., 2016)

Traditional energy trading is for the most part unidirectional. The electricity is in most cases transmitted from large-scale generators to consumers over long distances, while the cash flow goes in the opposite direction. By contrast, the P2P energy trading system is encouraging multidirectional trading within a local geographical area. In practice, this could mean that consumers would be able to buy electricity from the neighbour who is producing electricity by solar panels. (Zhang et al. 2018) As discussed earlier in this paper, this traditional arrangement with big power plants covering all the power demand could be replaced by a more integrated model, where consumption and power generation are located on the same grid level. (Blom, 2018)

Mylrea and Gourisetti (2017) also presented a P2P model, which highlights the application of blockchain technology to the smart grids, in order to reduce the costs by removing third parties and increasing arbitrage opportunity for people to produce and sell energy to each other. In their model, smart contracts are facilitating P2P energy exchanges by enabling energy consumers and prosumers to sell energy to each other, instead of transacting it through a system of multiple tiers, where distribution and transmission system operators, power producers and suppliers operate on various levels. Cost savings are not the only benefits blockchain could offer for the energy industry, as the transaction data might be more secure in decentralised storage with multifactor verifications of transactions in the blockchains distributed ledger. (Mylrea & Gourisetti, 2017; Hasse et al. 2016)

Their model works as follows: At the beginning, the electricity is generated as Consumer buys the electricity, the Blockchain-based meters update the blockchain, and creates a unique timestamped block, which can be used for verification in a distributed ledger. At the distribution level, system operators can leverage the blockchain to receive energy transaction data, which can be exploited to invoice their network costs from the consumers. Besides, the data requirements are reduced and the speed of clearing transactions for transmission system operators is increasing as transactions can be executed and settled based on the actual consumption. (Mylrea & Gourisetti, 2017)

Smart contracts execute and record the transactions in the blockchain load ledger utilizing blockchain-enabled advanced metering infrastructure, called AMI. These blockchain-based smart contracts can facilitate the consumer-level exchange of excess generation from distributed energy resources (DER), which in turn could provide additional storage and help the balancing of substation loads. According to Mylrea and Gourisetti (2017), this kind of P2P system could reduce or even replace the need for a meter operator, assuming that the meter blockchain is shared with the operator of the distribution system.

2.3.5 Energy Trading & Sharing Economy

This kind of development around P2P systems could assist the introduction of a sharing economy in the energy sector. The sharing economy is described as an emerging economy-technological phenomenon which is fuelled by the developments in technology, growing customer awareness, proliferation of collaborative web communities as well as social commerce. In practice, customers are happy to have access to services rather than owning products themselves as individuals. (Botsman & Rogers, 2010; Kaplan & Haenlein, 2010; Wang & Zhang, 2012)

The sharing economy is considered as an umbrella concept for several ICT developments and technologies, like collaborative consumption for instance, which endorses sharing the consumption of goods and services utilizing online platforms (Hamari, Sjöklint, & Ukkonen, 2016). Collaborative consumption is one of the concepts that could encourage the development of blockchain and smart contract systems in the energy sector and vice versa.

As the blockchain is a technology with a wide use case spectrum, it could be utilized in several different ways in the energy sector. Münsing, Mather, and Moura made especially interesting research in 2017, which studied the opportunities of the blockchain regarding the optimal scheduling of distributed energy resources. Besides, their study also included a market, which considers and sends out price signals based on the optimization results. (Münsing et al., 2017)
The foretold concept is particularly interesting because as Sabounchi & Wei in 2017 stated, the average prosumers in the local market do not possess the necessary time, expertise, and incentive to form a presented market. This is an important reason to study blockchains and smart contracts and how the applications of them could benefit the automation processes in the energy market.

In addition, Hahn, Singh, Liu & Chen (2017) stated that transactive energy is going to require support from the market to help the exchange of energy between many prosumers. As stated before, this development is introducing many challenges such as how to establish consensus and trust between transactive agents and how to exchange money after the transaction has occurred. Smart contracts and blockchain systems with digital ledgers are introducing unique contributions to these challenges. (Hahn et al., 2017)

There are still many uncertainties remaining at the large-scale implementation level regarding how the technology could fit into the current electricity market design. There are also many unanswered questions regarding the required characteristics of the blockchain, its consequences for existing and new market actors, economic and regulatory issues, and its impacts on energy market design. Blockchain could also further change the business landscape. These trends are allowing new business models to flourish, while small enterprises will continue to enter the electricity value chain to offer services and solutions for the smart grid-based value chain. (Orlov, 2017). The dimensions of smart grid systems are in essential role concerning the utilization possibilities of smart contracts and blockchain systems.

2.3.6 Existing concepts

One of the first widely known blockchain applications in the energy sector was the Brooklyn Microgrid, which was launched in a neighbourhood in Brooklyn, New York. The project included the successful implementation of a P2P electricity trading platform, which was based on the blockchain in a microgrid setting. (Orlov, 2017)

Already in 2014, Mihaylov et al. conducted case research where they created a system similar to tradeable green certificates. In their concept, the solar producer receives NRGcoins whenever they produce one kWh of energy, which the user in question can trade in an open market. The value of the coin at issue is controlled by the market. This concept is also explored in live projects, like Solarcoin for example. (Blom, 2018)

Start-ups and utility companies around the world have introduced blockchain projects, like Vattenfall in the Netherlands, Innogy in Germany, Power Ledger in Australia, and Wien Energie in Austria. These pilot projects and potential applications contained the complete electricity value chain: P2P and wholesale trading, metering, and billing, electric vehicle sharing and charging, and guarantees of origin (GOs). (Orlov, 2017; Klessmann et al., 2009)

One of the first use cases was demonstrated in April 2016, in New York, where the energy that was generated in a decentralised fashion was sold directly between neighbours through a blockchain system. This concept demonstrated that the energy producers and the consumers could execute energy supply contracts without involving a third-party intermediary. The concept effectively increased speed and reduced the costs of the transaction. (Hasse et al., 2016, Mylrea & Gourisetti, 2017)

Mannaro, Pinna & Marchesi (2017) presented a crypto-trading project (Figure 3), that is aiming to implement a blockchain-based system, which is extending the features of cryptocurrency exchanges to be exploited in the renewable Energy Market. The purpose of their project was to perform the following actions related to the area of specialization, which was Smart grids for the management of electricity. This included efficient management of energy demand and supply for improving the distribution networks and regulating the energy consumption from the energy-saving perspective. It also included monitoring and analysis of electricity consumption by final consumers (business and private). (Mannaro et al., 2017)

The above-mentioned actions were realized through the creation of a platform, which was based on a token system. It was used for the purchase and sale of energy enabled to record the amount of energy that was purchased. Each user in the system can become a holder of a specific amount of energy and resell it at any time at the bid price. The transition from virtual trading to energy delivery is decentralised in their system, exploiting energy-oriented systems, which are geared to new and advanced paradigms. (Mannaro et al., 2017)

Mannaro et al., (2017) also included the integration and development of smart contracts for the energy market in their on-going crypto-trading project (Figure 4). In their project, the smart contract will be analysed and designed for the management of the interaction among different tools (including IoT solutions), users, manufacturers, and the market, including the exchange protocols with other intelligent electricity grids. They aim to design an energy market that is allowing payments and quotations of electronic exchanges in cryptocurrencies. (Mannaro et al., 2017)

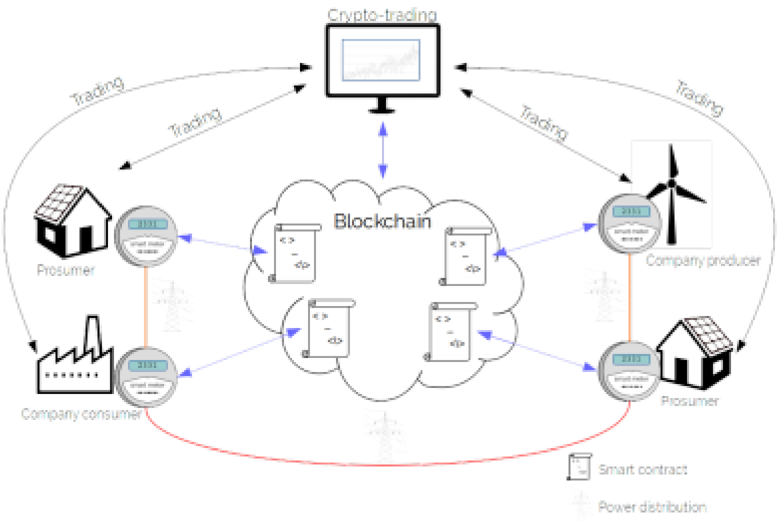

FIGURE 5 Representation of the Crypto-Trading system (Mannaro et al., 2017, pp. 4)

Mengelkamp et al. introduced another interesting concept in 2018. They modelled and simulated a system including 100 residential households where the market mechanism is more complex (Figure 5). They also added an economic analysis of the system. The used market in their concept is continuous, with a market-clearing every 15 minutes. All nodes are obligated in each step to send in their consumption for the next time step, and demand and supply are balanced in this matter. Ethereum was used as a protocol in their concept. (Mengelkamp et al., 2018)

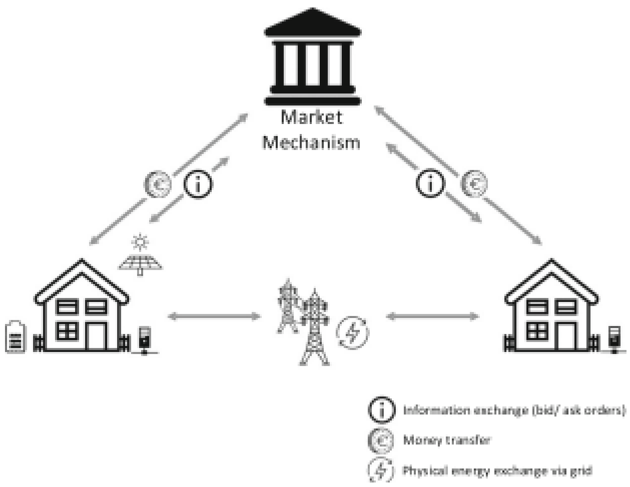

FIGURE 6 Concept of blockchain-based local energy trading (Mengelkamp et al., 2018, pp. 209)

Additionally, Sabounchi & Wei (2017) exploited Ethereum Blockchain in their research paper, where they proposed a P2P marketing model for electricity trading between local prosumers in residential microgrids. This idea of the P2P mechanism is already widely used in data transfer and communication.

Regarding the electricity market, structure, also referred as Transactive Grid, can be described as an electricity-marketing model where a substantial amount of the demand is delivered by local generation exploiting small-scale distribution generation units. If fully utilized, this kind of decentralised model could minimize the power transmission dissipation, minimize the load on the grid, and reduce the possibility of cascade failure due to its inborn capability of islanding.

In recent years, there has been a growing interest towards P2P trading in the industry. In 2015 Liu et al. proposed a paradigm of P2P energy sharing between neighbouring microgrids, with the goal the improve the utilization of local DERs and achieving savings for all microgrids. In 2017, Alam, St-Hilaire, & Kunz presented an integrated demand-side management system, which was coordinated with P2P energy trading with other households in the smart grid to minimize the cost of energy. Furthermore, Liu et al. (2017) proposed an energy-sharing model including price-based demand response, while Motalleb and Ghorbani (2017) presented a non-cooperative game-theoretical model of the competition between demand response aggregators for selling energy that is stocked in energy storage. (Zhang et al. 2018)

In a recent study, in Norway, Blom (2018) presented a blockchain-based model for a local energy market, where technical, economic, and regulatory analyses were performed. This is an interesting development for energy technology and business research in general, but especially for other Nordic countries like, which energy markets have similarities with Norway's energy markets. (Ma, Prljaca & Jørgensen, 2016)

Blom (2018) also introduced blockchain supported local energy market performed by Bremdal, Olivella, & Rajasekharan (2017), which utilized flexible loads in the system to balance supply and demand. The energy results showed that the blockchain is a promising platform to build complex applications. An interesting comparison between database solution and blockchain solution in a Local Energy Market (LEM) was conducted, and they declared blockchain to be superior of these two (Blom, 2018). These results are interesting concerning the data hub solutions Nordic countries have developed for their energy markets.

Hahn et al. (2017) presented an approach to support contract development based on blockchains, like the ones in Bitcoin and Ethereum, to organize a decentralised, public, and verifiable ledger and contracts of the pricing signals and transaction agreements necessary for transactive energy. Their paper introduced a smart contract that is implementing a transactive energy auction, which is operating without the need for a trusted entities oversight. The mechanism used in the auction is implementing a Vickrey second price, which will guarantee that bidders are submitting honest bids. The contract is implemented on transactive agents and on the Ethereum blockchain. The contract is then used to execute auctions.

One concept utilizing blockchain technology in the energy sector was presented by TenneT, which is a transmission system operator (TSO), with activities in the Netherlands and in Germany. Their pilot project goal was to solve issues related to climate dependency of renewable energy sources. The pilot is providing flexible capacities from an interconnected pool of electric vehicles and charging stations. They also have a pilot that controls home storage systems and adjusts their charging management in accordance with the individual grid situation. (TenneT, 2020)

Preceding concepts are just a few examples blockchain based smart contracts are offering for the energy industry and market. The opportunities are unbounded, although the industry itself is setting a substantial set of requirements and barriers for the development and deployment of new technologies.

2.3.7 Technological and Legal Requirements

Blom (2018) conducted a technical analysis of the blockchain protocol, which showed that blockchain can process high frequent market processes and that the design of trading mechanisms could be conducted with high flexibility. According to him, it is particularly interesting to register that real-time trading with 600 nodes and 5-minute trading frequency requires a blockchain system with the capacity to process 10.2 transactions per second. This is a relatively small amount of transactions per second, which is implicating that the computers need in the system do not have to be relatively powerful. (Blom, 2018)

However, Scherer (2017) presented that computation in a blockchain system must be done by all nodes that participate in it, which is increasing the computational usage of the system. As a result, the blockchain operation is more computationally heavy than a database solution (Scherer, 2017), which means that the energy consumption will be a challenge for a blockchain system (Mengelkamp, Notheisen, Beer, Dauer & Weinhardt, 2018; Truby, 2018). Similar conclusions were made in the inquiry, conducted by Fingrid and the Ministry of Economic Affairs and Employment of Finland (Fingrid & TEM, 2018).

Blom (2018) also identified storing different kinds of variables being the most computationally expensive operation in the blockchain environment. In addition, Truby (2018) argued that the energy-intensive design of many blockchain solutions means that combined they are posing a serious threat to EU's commitments to reduce the amount of greenhouse gas emissions. Especially, the mining and trading system of Bitcoin requires a vast amount of energy (Truby, 2018).

Blom (2018) also noted that the current regulations in Norway are not designed for a system with a high share of distributed production. As the markets and legislations are relatively similar, it should be noted that the new kinds of systems in the energy sector would need examination and possible rearrangement of regulations in the industry. To illustrate the problem, Blom (2018) is showing that currently, it is more profitable to store the energy in batteries than it is to sell it.

In Finland, the legal aspects of blockchain and smart contract systems have been researched on a more general level. According to Lauslahti, Mattila & Seppälä (2016), the significant question is the juridical status of smart contracts. There are a countless number of usage possibilities for smart contracts. In some cases, it is clear that they are not fulfilling the contract criteria, while in other cases they are probably fulfilling the contract criteria in current legislation. The most significant issue concerns the contracts that are more difficult to define. On these occasions, the important question is that who can define the juridical legitimacy of these contracts. (Lauslahti et al., 2016; Fingrid & TEM, 2018)

Blockchain technology and smart contracts could provide some arguments to loosen up the regulations and make end-users more active players in the market. This development can be seen as a realistic option because of the neutrality and third-party independence of smart contracts, as these technologies could make it easier to connect end-users without the interference of another third party or an energy retailer. (Blom, 2018)

Even though it seems like the blockchain and smart contract systems are not setting insurmountable obstacles for the information systems and infrastructure, the desired benefit of them could be limited due to their level of energy consumption. However, this aspect does not mean that these matters should not be studied in the future as the technology and the systems develop rapidly. It should also be noted that the capability to process transactions in an energy-efficient matter is just one part of the technological requirements. The application of blockchain and smart contract systems in the industry would probably place a new set of requirements for many appliances and systems, which is further indicating the complexity of the energy sector itself.

2.4 Summary of literature review

The changing requirements and new technologies for energy production are forcing the energy market and the energy provider sector to develop. The application of renewable energy resources and the pressure to develop more and more efficient energy systems is urging the industry to find new alternatives to generate and distribute energy. In the European Union and especially in Finland, the ambition towards higher energy efficiency and carbon neutrality are shaping the field for large technological changes.

At the same time, the introduction of blockchain and smart contract systems have offered new kinds of opportunities for many different industries. This development has touched the energy industry as well as there has been a growing number of researches made around the opportunities blockchain technology and smart contracts.

Large parts of these opportunities are related to how the energy sector could work more efficiently. Many concepts and systems have been developed, and they have introduced new ways for energy producers and consumers to participate in energy production.

This change from traditional large energy plants towards more integrated and distributed models where producers and consumers reside on the same grid level (e.g., same community) could be considered as one of the most important changes in the energy industry, where blockchain and smart contract systems could have a major role being and enable and ensure distributed efficiency.

Overall, the benefit of transitioning from traditional systems to blockchain-supported systems is the exploitation of automation, which in turn creates conditions for achieving efficiency. In return, this could create more opportunities for prosumers to be active in energy production and achieve financial benefits by selling electricity that is produced with solar power for example. Blockchain-based systems could also offer a wide range of new business opportunities and reshape the energy market in return.

However, the realization of these developments is still uncertain, at least. Even though many successful concepts have been presented, there are large obstacles regarding technology, legislation, and business. In Finland, the deployment of Datahub has been postponed to 2022, while in the Nordic countries the introduction of the 15-minute imbalance settlement period has been postponed (Nordic Balancing Model 2019). These delays are showing how slow and rigid the development is in the highly regulated energy industry.

The characteristics of the industry should be noted as well as matters concerning the legislation and business in the industry. While these matters could be hindering the development of the industry, it could also give time for technology to mature before the possible implementation of it.

3 RESEARCH METHOD

The qualitative research method is suitable for this research because the topic and research problem are relatively new, which is the reason there are no completed theories to answer the problems. Qualitative methods are also the best method when the goal is to understand the research subject on a deeper level and find new observations regarding the subject in question.

This qualitative research was realized by leveraging the case study method. The case study is a suitable method in the preliminary phases of research when the research problem is still unclear. The strength of this method relates to its ability to discover a wide variety of cultural, political, and social factors that may not be known in advance but are potentially related to the phenomenon of interest. A case study is an ideal strategy for exploratory research. (Bhattacherjee, 2012) Thus, it is a suitable method for conducting this research.

The data gathering for this research was implemented as a semi-structured interview, also known as theme interview. The interview process included structured questions and open discussion. In accordance with the survey research method, the face-to-face interview is suited best for the researches that are studying individual persons (Bhattacherjee, 2012).

The interviews are a more personal way of gathering data, compared to structured surveys and they enable the interviewer to make more specifying questions to clarify answers that were given by the interview partners (Bhattacherjee, 2012). The main idea of the interviews is to approach interview partner through conversation, in order to get first-hand about their experiences around the subject that is being studied (Schultze & Avital, 2011). The aim of the interview process is to investigate how experts in the fields of energy business and/or blockchain and smart contracts systems see the possibilities of these technologies in the energy sector. The subject that is being researched has not been studied widely yet and it can be better described utilizing qualitative research methods.

3.1 Data collection

The data collection process was implemented between March 2020 and May 2020, utilizing semi-structured interviews. The invitation to interviews was sent to 18 persons who are working in Finland and are experts in the field of energy business and/or blockchain technology and smart contracts. Seven persons attended interviews, which means that 39% of the people that were connected also participated in the study. Due to the COVID 19 situation, the interviews were arranged to utilize Microsoft Teams video conference tool. The data collection process included the preparation of the interview structure, the acquisition of interview partners, and the implementation of the interviews.

Semi-structured interviews are often described as theme interview, as it is being directed to certain theme-based questions. The structure of the interview was built based on the themes that were presented in the literature review. This structure was used to help the interview partners to get absorbed into the problem, handle it, and discuss it on a deeper level. The themes of the interview structure are interview partners' background and knowledge about the subject, how the energy sector is currently working, and how blockchain and/or smart contracts could be utilized in the energy sector. (Longhurst, 2003)

The goal of the background related questions is to give interview partners the opportunity to clarify their knowledge about the energy sector, and the blockchain and smart contract systems. This information is useful for assessing interview partners' level of expertise concerning the areas of the study.

The questions concerning the current situation of the energy sector are clarifying the current situation of the industry and introducing how interview partners perceive it. These questions are also encouraging the interview partners to consider the situation of the energy industry from multiple angles to discover problems and possibilities. At the same time, these questions are also laying the foundation for reflecting how blockchain technology and/or smart contracts could be utilized in the energy industry.

The section on blockchain and smart contract systems utilization possibilities in the Finnish energy sector was started by finding out how much interview partners have knowledge about the technologies in question. The interview partners explained their level of knowledge, and how these technologies could be exploited at the general level. These discussions then laid the foundation for more profound considerations of these technologies and their usage possibilities. More precise questions in this area encouraged interview partners to think and compare potential use cases of blockchain and smart contracts technologies, their business and technology-related risks and opportunities, and what needs to be done before it would be realistic to put this kind of technologies into practice.

3.2 Data set

The data set consists of experts or knowledgeable informants in the areas of blockchain and smart contracts systems and/or the energy industry. Due to the novelty of this research topic, there are few people in Finland who could be described as experts. As a result, many interview partners were experts only in one area and had passing knowledge in other areas. Therefore, a limited number of suitable interview partners meant that the interview partners were directly contacted by email, and the data set was anonymised for this research.

The seven persons who participated in the interviews formed the sample of the study. Out of those seven persons, two worked for a non-profit organization and five worked for public companies, which play a major role in the Finnish energy industry. Interview partners' background information is presented in Table 2.

In general, though, interview partners are curious about this novel and unexplored research topic, as the interview partners are working in this specific industry and are aware of the potential of blockchain systems. Contacted persons worked in different kinds of organizations in the energy industry. These organizations included energy Retail Companies, IT Service Providers, interest organizations, and Transmission System Operators in the industry. The differences in the working backgrounds were pursued in order to gain enough variation between interview partners. The goal of this sampling was to interview people, who had broad knowledge about the research area and could provide a profound understanding of the industry and its preparedness to utilize the technologies in question.

Even though the sample is not large, it is still quite extensive. The interview partners come from different kinds of organizations, work in different roles, and have a different amount of work experience in the energy sector. The target of the interviews was to get information from different perspectives to survey ideas from a larger area of the energy sector. The novelty value of responses was also pursued, which is the reason why not all interview partners have been working in the industry for many years.

TABLE 2 Interview partners' background information

Interview partner	**Employer**	**Role**	**Work Experience in the Energy Sector**
Interview partner 1	IT Service Provider	Product Manager	4 years
Interview partner 2	IT Service Provider	Head of Business Development	10 years
Interview partner 3	Non-profit Organization	Executive Senior Advisor in Energy Markets	20 years
Interview partner 4	Non-profit Organization	Senior Advisor in Energy Networks	10 years
Interview partner 5	Energy Retail Company	Customer Relationship Manager	20 years
Interview partner 6	Energy Retail Company	Security Manager	Under a year
Interview partner 7	Transmission System Operator	Specialist in Markets	Four years

3.3 Data analysis

According to qualitative data gathering methods, the data analysis methods need to be qualitative as well (Bhattacherjee, 2012). The data analysis was realized through utilizing qualitative content analysis, with the approach of conventional content analysis (Hsieh & Shannon, 2005). This method is generally used in studies, which try to describe a phenomenon, which in this case is the technology in question in the energy sector. The approach is usually appropriate in cases where existing or research literature considering the phenomenon is limited.

In this method preconceived categories are avoided as categories and names for categories can flow from the data (Kondracki & Wellman, 2002). To enable emerging of new insights, the researchers are immersing themselves into the data. Large proportion of qualitative methods share this initial approach to study design and analysis. (Hsieh & Shannon, 2005)

The phases of the data analysis included the transcription of interview data, reading the material, thematization, coding and categorization of the data, finding relations, links, differences, and new observations from the answers, and reporting the results.

The first phase of the analysis was transcribing the interview recordings to text format. Each interview was transcribed into its own text file, which included the entire interview. During the transcribing process, the recordings were processed thoroughly, and their equivalence with the transcriptions was ensured.
The second phase of the analysis was reading the material. In this phase, the goal was to get familiar with the material and understand it in more profound level,

so that it would be easier to recognize different kind of observations and raise thoughts and questions for the analysis.

In the third phase, the data was read word by word to derive codes. The phase started with the process of highlighting exact words from the text that seemed to capture key concepts or thoughts. This was followed by making notes of first impressions and thoughts and forming initial analysis.

Thematization was carried out by recognizing the key themes from the data set and by assembling them into their own text files. Themes were defined by comparing the data set to findings based on earlier research. Observations about a specific theme were coded into separate text file. Thematization helped to separate the themes that were relevant for the study, based on which the structure of the interview was formed. The used codes in thematization: Interview partners' background information, Current state of the energy sector, Emerging trends, Tension points, the most important stakeholder, Regulations, Technology related opportunities and obstacles, and Market dynamics related opportunities and obstacles for blockchain and smart contract systems in the energy sector. Codes that were recognized form the data set were assembled to their own theme-based files for the next phase of the analysis. For example, when searching for observations related to the emerging trends in energy sector the goal was to identify sentences, which belonged to that specific theme:

"The servitization in the first place will be a trend in the energy industry like in any other industry".

In the next phase of the analysis different elements inside these themes were identified through categorization. The codes for categorization were defined based on the observations made from earlier research. However, there were few new elements recognized during the interviews as well. The categorization assembled sentences, which were included to the category of research. For example, when the goals was to recognize what are the performance and capacity related opportunities and obstacles for blockchain and smart contract systems in the Finnish energy sector, the aim was to identify sentences which are discussing performance and capacity related opportunities and obstacles for blockchain and smart contract systems in the Finnish energy sector:

" The risks may be related to performance and capacity.

Finally, the coded data was analysed, both quantitatively and qualitatively to specify which themes occur most frequently, how they are related to each other and in what contexts (Bhattacherjee, 2012). The analysis of the material including thematization, categorization and coding of the research data was executed using MAXQDA Analytics Pro 2020 -software. Preconceived categories were not used as categories were allowed to emerge from the data.

4 RESULTS

This main chapter is presenting the results of the empirical study. The first part of the chapter is discussing the current state of Europe's, Nordics, and Finland's energy industry. The second part of the chapter is presenting emerging trends in the energy sector, which is followed by third chapter demonstrating the tension points in the energy sector. The fourth chapter discusses about the most important stakeholders of the industry and the fifth chapter the regulations concerning energy sector. The sixth chapter is demonstrating technology related results and seventh chapter is discussing results concerning market dynamics. From second sub chapter onwards, the results are discussed from Finnish energy sectors perspective, if not stated otherwise.

4.1 Current state of energy sector

This section is presenting the research results concerning the current state of the energy sector in European, Nordic, and Finnish energy markets. The first part is discussing the state of energy markets in general at the European level. This is followed by a more detailed analysis of Nordic energy markets. Finally, the results concerning the state of Finnish energy sector are presented.

4.1.1 European energy sector

The results suggest that there are a lot of differences between European countries regarding how they have organised their energy markets (Table 3). The Nordic energy markets are the most advanced in Europe according to the interview partners' answers. Despite of these large differences between European countries, two of the interview partners mentioned pan-European cooperation, in the energy sector as highly probable development in the future. In practice, pan-European cooperation would mean moving towards European-wide electricity wholesale markets.

> "But this kind of pan-European electricity market, like wholesale market and at some point, retail markets at least in the Nordic countries. At least in my opinion, this kind of unification is inevitable in the future."-Interview partner 2

> " …It has stared from this kind of regional cross-border integration, cross-border integration, and how the direction anyway is towards the Pan-European framework. To this market integration also related are the physical electricity connections, which are significantly expanding." -Interview partner 7

Regarding cooperation between European countries three interview partners also mentioned the development of market harmonization. This kind of development is pursued by the European Union, which is reforming legislations in order to harmonize the energy markets inside the union. It was also pointed out that in general level European energy industry is in the middle of substantial changes.

> “We've got quite a bit of new legislation coming from EU, which is harmonizing the market a bit.”-Interview partner 1

> ” The whole energy industry in European level is in the middle of major changes.” -Interview partner 3

Two out of seven interview partners mentioned the level of integration between different sectors. Interview partners claimed that electricity markets and other aspects of it are becoming more integrated with each other. At the same time, this was considered to be an issue, where large differences between European countries occurred.

> “Integration of electricity markets and energy markets and the underlying systems is in different phases in different countries.”-Interview partner 7

Overall, the results are showing that there are large differences in the ways European countries have organised their energy sector. Based on the results it was also evident that practices and systems in the Nordic countries were advanced compared to other European countries. This aspect is further discussed in the following chapter presenting the current state of the Nordic energy sector.

TABLE 3 Current themes in the European energy sector

Code	Percentage of observations (%)	Amount of observations (pcs)
Differences between countries	71,4%	5
Pan-European cooperation	28,6%	2
Legislation changes	28,6%	2
Harmonization	42,9%	3
Sector Integration	28,6%	2

4.1.2 Nordic energy sector

The interview partners saw Nordic energy markets as one of the most developed energy markets in the world. The markets in Nordic countries are highly integrated and highly regulated, and they are working relatively well according to the interview partners. Many of the interview partners also saw that Nordic countries have been the forerunners in developing energy markets towards more integrated models.

> "The way our wholesale markets and retail markets can work together and manage this whole balancing of the electricity system market based on markets. In our Nordic level it is top of the world." -Interview partner 2

> "The current market model, where different markets are continuously integrated with each other. Not going to details now. But it started in a way from Nordic countries and if you look at the market model which is used in many countries, it is a very Nordic country based on my perspective."
> -Interview partner 7

Moving to a centralised information exchange system through different data hub projects was raised by interview partners as one topical aspect of the Nordic electricity markets. These projects are in different phases in Nordic countries, but they will unify the electricity markets between the countries.

> "The ongoing substantial changes can be concretized to projects around data hubs in different Nordic countries, which will harmonize the markets."
> -Interview partner 5

European energy markets are heterogeneous, and Nordic countries have one of the most developed and integrated markets in Europe, which may serve as a blueprint for other European markets as well. Correspondingly, the Finnish energy sector is firmly connected to the Nordic energy sector, as there are many similarities in the systems and the processes.

4.1.3 Finnish energy sector

In general level interview partners saw the Finnish energy sector as one of the most developed in Europe. Finnish energy markets were described as well-functioning and competed markets. According to results, one of the main reasons for the Finnish market's advanced position is the utilized imbalance settlement period-based metering process, which is enabling a different contract structure than a curve-based balance settlement.

> “Especially in Finland we are, in a way, in a lot more developed state comparing to other countries in Europe. Merely, because we have comprehensive imbalance settlement period-based metering, which enables different kinds of contract structure and different kind of aspects than load curve-based balance settlement.” -Interview partner 4

> ” We have well-functioning and competed energy markets, which are going through big changes.” -Interview partner 5

The Finnish energy sector is highly interconnected with other Nordic countries in many different ways that have been presented in this study. As a result, reforms in the Finnish energy sector need to be designed acknowledging the impacts on the Nordic scale. Overall Finnish and other Nordic energy markets are one of the most developed in the world. While the level of advancement offers opportunities for new solutions to emerge, it also means that completely new and disruptive technologies need to convincingly demonstrate their benefits for entering the industry on a large scale. However, climate change and the increase of weather dependent renewable production is reshaping the industry in Finland. This perspective and other emerging trends in the energy sector are discussed in following chapter.

4.2 Emerging trends in the energy sector

This subchapter is presenting the research results regarding the emerging trends in the energy sector. In this research, emerging trends are meaning topical points of discussions in the energy sector and repeatedly presented future developments. In total, 16 trends were identified from the data set. They are presented in table 4.

4.2.1 Climate change

Even though climate change itself was mentioned by only one interview partner, climate, and environment-related issues (renewable energy sources, wind, solar, reducing carbon emissions) were raised by five out of seven interview partners

(71,4%). Results are showing that the environmental issues and the urge to increase the number of renewable energy sources and reducing carbon emissions are one of the main trends in the energy sector. However, the presented development is increasing the volatility of the electric system, which is creating new challenges for the industry according to the interview partners.

> "Climate change, which is creating a huge urge to reform this electricity industry, increase renewable energy and new ways to manage this electric system." -Interview partner 3

> "Lots of companies are investing in wind turbines. That leads to some instability or high volatility in the networks and that creates certain challenges as well." -Interview partner 1

> "…large-scale deployment of wind and solar power and especially the implementation of wind power on Nordic level, on European level, will or is currently playing a big role in this electricity system and electricity markets, so that the whole markets are becoming more and more volatile." -Interview partner 2

Overall, sustainability is a major goal for the energy sector, and it is pursued by the increase of renewable energy sources and reformation of the energy system. Proposed actions for sustainability are however setting new substantial challenges for the whole industry. The energy sector could overcome these challenges utilizing new technologies.

4.2.2 Development of technology

The development of technology was mentioned by three out of seven interview partners. The interview partners saw the development of technology as an aspect that is inspiring changes in the industry as itself, but also giving solutions to issues caused by other factors.

> "And simultaneously this huge technological revolution, aka digitalization…blockchains, IOT, Big data, data analysis, all of these." -Interview partner 3

> "…But at the same time all of these IT structures and technologies, which are enabling it. They are both driving each other forward."-Interview partner 7

Development of technology is tightly connected to the development of energy sector and its practices. They are both urging each other's to reform and develop, which is needed as the requirements for energy systems are changing.

4.2.3 Volatility of the markets

The results also showed a growing concern regarding demand response management in the electric system. As more and more renewable energy sources are implemented, the weather dependency of the electricity system is increasing. As a result, the volatility of the markets is increasing as well, according to the interview partners.

> " The production levels will change significantly faster than they do today, so the influence is larger. And we cannot control it. So, the market needs to be able to take that into account and the main job for the market is to create economical foundation for balancing production and consumption to make this system work." -Interview partner 2

Presented development is creating a growing need for improving methods concerning the demand response ability of the electric system. The electricity market needs to find the means to balance production and consumption levels.

4.2.4 Real-time trading

Relating to the issue of growing volatility, three interview partners raised the development of real-time trading as an emerging trend of the energy sector. The results are showing that the trading is moving closer to the delivery time and it is done in shorter units. The goal of this development is to make the system more flexible and enable it to react to changes in production more swiftly.

> "On the energy markets side, I would see that there is an automation and real-time trading, so that trades are done according to algorithms and closer to the delivery time." -Interview partner 7

> " The trend is for trading to take place closer and closer to the delivery time… And the other trend is that, if currently the trading is done by the hour, so in the future it will be fifteen minutes and possibly sometimes it will be shorter than that. So, it is divided into smaller pieces, to a way where trading is done in shorter units and closer to the delivery time. This will require more capacity and ability from metering and information systems." -Interview partner 3

Dividing trading into smaller units will require more capacity and ability from metering practices and information systems.

4.2.5 Decentralised production

Interview partners also raised the development of decentralised production increasing the proportion of renewable energy sources and weather dependent production. As a result, the need for flexibility in the energy system is increasing. This perspective regarding the demand response abilities of the electric system was raised by three interview partners.

> " There will be new kind of production, more decentralised production and as a counterbalance to this, there will be growing need for flexible resources to both production and consumption. For example, the consumption flexibility of households is in front of large change, or the urge towards the change is substantial and all kind of flexible consumption, also smaller, decentralised resources will be coming valuable." -Interview partner 3

In many cases decentralised production has been used a synonym for local production or small production. In practice, all of these can mean production which is done using smaller units and they are located nearer to their delivery site.

> "… Also, the demand response, how can small producers be a part of it, help it with different solutions when the consumption is at top levels, so that possibly electricity can be moved back to the grid from the end users."-Interview partner 6

Increasing amount of decentralised production is reshaping the industry as the energy generation transforms from large power plants towards smaller production units. This development is also creating opportunities for consumers to produce energy and participate to the market.

4.2.6 Active consumers

The results are also showing growing trends towards more active consumers, who have more options regarding their consumption of energy. Interview partners raised that in the future it will become more profitable for consumers to produce energy and act as prosumer. The development of technology and infrastructure is going to make it possible to retain and sell energy and manage the balance of consumption and production in a more efficient way.

> " … the growth in activity of customers and growth in options for customers, that is one trend and it is discussed a lot." -Interview partner 3

> " From the consumers perspective, from there will rise changes, like for them it will be more cost-effective to produce their own energy. Electric cars, through them the storing of energy might become more common to households. The intelligence (home automation) is also coming to households, so that the management of own production, storing of energy, buying energy and all of this will become easier for consumers as well, when homes will get the intelligence and the automatic system, which will handle the management of these on behalf of the customer." -Interview partner 3

Overall, the structure of the energy market is changing as customers are no longer just passive participants in the market, who only purchase electricity. Consumers are becoming more active and some of them are acting as prosumers as well.

4.2.7 Servitization

The development towards servitization and introduction of new types of services is also affecting the energy industry according to three interview partners. The customer base is diversifying as some consumers are taking initiative and others are staying as relatively passive consumers.

> ” We will have customers of various types, who will want different kinds of service and are willing to do things in different ways. The servitization in the first place will be a trend in the energy industry like in any other industry.”-Interview partner 4

Overall, the development of servitization is creating new service models for the energy industry and reforming energy companies’ ways to do business. Diversifying the energy market is creating new challenges, as the companies in the industry will face more versatile requirements concerning the services they provide.

4.2.8 Mergers and new entrants

One interview partner also raised the development regarding mergers as one emerging trend in the energy sector. Smaller companies are creating alliances to be more competitive. However, at the same time, new entrants are joining the market as well, which is reshaping the competitive situation.

> “Traditional energy utility companies seem to; especially smaller ones seem to be merging. They are creating alliances. There are several examples of this in the Nordics. In addition, there's new entrants. So, I think in total the amount of market participants has actually even grown, even though the older ones have done mergers.” -Interview partner 1

How these trends are affecting the solutions that are implemented in practice remains an open question for the energy sector. There are questions concerning practicalities and regulations for decentralised production, small production, electric vehicles, and energy communities.

> ” How the endpoint of customers is entailed to the market inside the next five to ten years. So, what will come of different communities, neighbourhood solutions, electric traffic, small production as a whole, and then around it the steering of decentralised production, which will be one of the

> biggest questions and how it will be solved in the next few years." -Interview partner 5

From the perspective of blockchain and smart contract systems, the emerging trend of an increase in renewable energy sources is interesting for numerous reasons. The addition of renewable energy sources is causing changes in systems at the general level, which can be beneficial for the presented technologies as the practices and processes are changing, which can create opportunities for new technologies and solutions.

The addition of small and local production can open avenues for blockchain and smart contract systems. This is especially the case when the implementation of small production leads to the introduction of energy communities and peer-to-peer networks. In theory, the internal trade in these energy communities could be managed to utilize blockchain and smart contract systems. This possibility is further discussed in chapter 4.7.3.

The results showed that a large part of the emerging trends was connected to climate change and the growth of weather-dependent renewable energy sources in energy production. Changes in market dynamics through more active consumers, new services, mergers, and new entrants were raised during interviews as well. A large part of the emerging trends is also creating tension points in the energy sector.

TABLE 4 Emerging trends in the energy sector

Code	Percentage of observations (%)	Amount of observations (pcs)
Climate change	14,3%	1
Renewable energy sources	57,1%	4
Wind energy	28,6%	2
Solar energy	14,3%	1
Reducing carbon emissions	28,6%	2
Volatility of the market	28,6%	2
Real-time trading	42,9%	3
Decentralised production	14,3%	1
Automation	28,6%	2
Development of technology	42,9%	3
New services and servitization	42,9%	3
Demand response	42,9%	3
Small production	42,9%	3
Active consumers	71,4%	5
Mergers	14,3%	1
New entrants	14,3%	1

4.3 Tension points in the energy sector

This subchapter is presenting the research results concerning the tension points in the energy sector. Raised aspects might be something that is causing disagreements between participants of the industry or creating challenges in the industry on a more general level. In total, 17 tension points were identified from the data set. These are presented in Table 5. The results showed that many of the tension points were connected to the emerging trends presented in the previous chapter.

4.3.1 Volatility of the markets

The results are showing that the urge to reform the energy industry is caused by the need to preserve the environment and prevent climate change. Renewable energy sources like wind and solar power have been presented as a solution to this issue, and they have been a growing trend in the energy industry. However, the volatile nature of wind and solar power is causing a lot of stability issues, because increasing their proportion of total production will also increase the weather dependency on energy production. This kind of development can create new tension points in the energy sector.

> ″ There will be a need for more flexibility for the system and how new methods are managed in a way, which will preserve the security of energy supply.″ -Interview partner 3

In the previous chapter, the development of small or local production and energy communities was described as one emerging trend in the energy sector. The introduction of a new kind of production and participants to the market might cause issues on a system level, but it could also increase the volatility of the system as the local production most likely will be weather dependent and unpredictable in a sense.

> ″ There will be a lot of local production, which behaviour may be weather dependent and unpredictable.″ -Interview partner 3

Increasing amount of renewable energy sources is increasing volatility in the energy markets as energy generation becomes more unpredictable. This development is causing tension points in the future, as the ongoing development sets new demands for the flexibility of the energy system.

4.3.2 Local production

In addition to the possible future problems concerning local production, there are already observable tension points currently. For instance, there are solar panels that are appearing in different places without the Distribution System Operator (DSO) being informed about it.

> “DSO's I know have problems with solar panels appearing in places without them being informed.” -Interview partner 1

In the European context, the grid capacity could prove to be a tension point regarding the introduction of local production by solar energy for example. According to the results, this issue should not be a significant problem for Nordic countries, but it should be taken into consideration in the Nordic countries as well.

> “But in Central Europe, the discussion is concerning the aspect that the grids are weaker than in Finland, and for example, solar energy is not fitting into the grid as easily.” -Interview partner 4

Local production is creating tension points to the energy sector currently and in the future. The practicalities to implement local production are not clear, which is raising tension already. As the local production increases, there will be more tension points as the grids might not have capacity for it.

4.3.3 Demand response and Security of supply

The issues regarding grid and production capacity were discussed as well during the interviews. Currently the security of supply is in high level in the Finnish energy sector. However, moving towards weather dependent production is causing problems from the perspective of demand response.

> "We need a lot more flexibility to the system and new methods to manage it in a way that will preserve the security of supply, which is on really good level in our electricity system." -Interview partner 3

The increases in weather dependent, decentralised and local production will create new tension points to the energy sector as the systems need to be updated to manage new requirements.

4.3.4 Real-time trading

One demonstrated emerging trend was moving towards real-time trading, which could increase the flexibility of the energy system as the trading would be conducted in shorter time units. This development towards faster trading cycles is however possibly causing more pressure towards the acquirement of electricity and energy portfolio management. Presented development will probably mean new challenges for risk management as well. These kinds of challenges could be a tension point in the energy sector.

> " When the system is changing and predicting the prices will move towards a more real-time direction, balances will change, trading will change to faster cycles. It will create more pressure concerning retail sales and acquisition of electricity, to know how to acquire electricity and manage the contracts in a way where protection is in order and the portfolio management will rise to a completely different level than it is today from the perspective of trading and risk management." -Interview partner 2

In practice, this means new challenges for electricity companies in acquiring electricity and selling it at appropriate prices. As trading is done in shorter units, the processes become faster, and the number of them increases, which will create new challenges for the energy companies and their information systems.

4.3.5 Complexity of the systems

The demonstrated path of development is also going to increase the complexity of the systems in use, which in turn will create new kinds of needs for the system development. At the same time, the speed of changes itself is creating significant challenges for the entire industry.

> ″ I would say that the speed of change is one of the biggest challenges.″ -Interview partner 7

> ″ There will be new kinds of needs, as the system becomes more complicated.″ -Interview partner 3

As the production is becoming more and more unpredictable through the increase of renewable energy sources, the demands towards the flexibility of the electric system are growing. These demonstrated changes to complicated systems are difficult to implement as the electric system has its principles regarding the security of supply.

> ″ … Energy infrastructure are complicated systems and systems which have to be used to maintain the society in operation, so when making changes to these systems you must always consider security of supply.″
> Interview partner 7

> "… there are constantly forming larger and larger electricity retails companies, which is the direct result of the industry becoming technically more challenging in more ways than one.″ -Interview partner 2

As the systems become more complicated the demands towards electricity companies are growing as well. This development has affected the market as the smaller electric companies have merged with larger ones.

4.3.6 New entrants

The ongoing changes are also persuading new entrants to enter the market as described in the previous chapter. The introduction of new operators to the market might cause issues and there is at least the need to find common ground rules in order to allow new entrants participation without jeopardizing the functionality of markets.

> ″ …need to find common ground rules, so that the new entrants can participate on an equal footing without endangering the functionality of the markets, their cost-effectiveness or shared principles.″ -Interview partner 3

> "Second is from utility company point-of-view, well, I think they have problems with new entrants' business-wise, that is probably good from the sake of the whole system though."– Interview partner 1

Overall, new entrants may offer new kinds of solutions and services, which could create tension points to the sector. However, from the consumers perspective new entrants should be a positive aspect as the competition situation in the market intensifies.

4.3.7 Electric vehicles

The substantial increase in the usage of electric vehicles will also produce new challenges to the energy sector as they are going to add new kinds of consumption, which will create new demands for the grid.

> "adding things like an electric vehicle will cause problems, but I think Finland and Nordics will be quite fine with that. We have pretty robust networks due to sauna's and stuff." -Interview partner 1

From the Finnish energy sector perspective, the preparedness level for this kind of development would be relatively high due to networks being quite robust. However, increases in electricity consumption caused by electric vehicles can create issues if this kind of new consumption will create new demand peaks (Fingridlehti, 2018b). Because of this aspect, the energy system needs solutions that can automatically balance the consumption levels. In an ideal situation, electric vehicles could offer flexibility for the electricity system by feeding surplus energy back to the grid (Fingridlehti, 2018b).

4.3.8 Technological issues

In addition to these presented aspects, many technological issues could cause problems in the energy sector. Moving to a datahub is changing the competitive situation, but it is also causing some technical challenges for the energy companies.

> "But other technical problems too I guess, concerning hubs and things like that too." -Interview partner 1

Old information systems are also causing a different kind of issues in the industry. In some cases, energy companies might face issues realizing business opportunities because of information systems of poor quality for their needs.

> "Old information systems are also problematic for in many cases. They (energy companies) might have problems realizing the business opportunities due to those" -Interview partner 1

Overall, technological issues are causing many tensions in the energy sector. However, in general, they were not highly emphasized by the interview partners.

4.3.9 Polarization of the market

The polarization of the market is one tension point of the energy sector. There are different kinds of operators in the market with different views on how the development of business activities should be managed in the energy sector. Many companies want to develop the industry through new innovations and technological development, but some companies want to slow down the speed of changes in the industry.

> ” The market is roughly speaking divided into two sections. There are parts of the companies, which are pretty much on board with the reforms if you think about how the energy market is working and with what kind of ground rules and how free competition perspective it has. Then there is maybe the other group in the smaller end, which tries to be on the other side in a way, that if something is not mandatory to do, then it should not be done.” -Interview partner 5

This kind of polarization in the market is causing issues for the whole energy sector as some participants are restraining the developments and others are promoting them. As a result, many reforms are realized relatively slowly.

As discussed, tension points are in many cases related to the emerging trends. While climate change is promoting the implementation of new products and services, it also creates new tension points to the market. Especially the increase in weather-dependent production is creating new tension points as the production becomes volatile. Simultaneously the industry is trying to move towards real-time trading in order to have better flexibility from the perspective of demand response, while technological issues related to old information systems are creating challenges for the operators in the industry.

From the perspective of blockchain and smart contract systems, the tension points can be seen as opportunities or as obstacles. Climate change-related issues and moving towards real-time trading are creating avenues for solutions that are able to increase the efficiency of the system. However, the polarization of the market and the complexity of the systems might create obstacles for introducing new solutions. The role of legislative issues is substantial as well, and it is enhancing the roles of local authorities as one of the most important stakeholders of the industry.

TABLE 5 Tension points in the energy sector

Code	Percentage of observations (%)	Amount of observations (pcs)
Volatility of the market	42,9%	3
Local production	28,6%	2
Grid capacity	14,3%	1
Energy communities	28,6%	2
Demand response	28,6%	2
Security of supply	42,9%	3
Real-time trading	14,3%	1
Complexity of systems	28,6%	2
Speed of change	14,3%	1
Mergers	28,6%	2
New entrants	14,3%	1
Electric vehicles	14,3%	1
Data hubs	42,9%	3
Old information systems	14,3%	1
Other technical problems	28,6%	2
Polarization of the market	28,6%	2

4.4 The most important stakeholders in the energy sector

This subchapter is presenting the research results regarding the most important stakeholders of the energy sector. In total, ten different types of stakeholders were identified from the data set. These are presented in Table 6. The results showed that the European Union, governmental bodies, and local authorities are significant stakeholders in the energy sector. Different kinds of operators in the industry and the energy market were also mentioned during interviews as well as consumers in general.

4.4.1 National Government and Local Authorities

Many of the themes that came up during the discussions concerning emerging trends and tension points were raised in discussions regarding the most important stakeholders as well. One aspect that was raised in almost all discussions was the role of government, legislators, and the local authorities. The energy industry was seen as a highly regulated industry, where large investments are needed, which means that the decisions made by the authorities have significant effects on the industry itself and to the market participants of it.

> ” Well the authority perspective is, of course, something that comes straight from the legislation and the obligations coming from it.” -Interview partner 5

> ”…and then one crucial role in our industry is a legislator and supervisory authorities because this a very regulated industry and it is very investment-oriented, that for us it is very essential that regulation in our industry is persevering and stable, as when an investment is made it should be possible to see the development in the long term.” -Interview partner 3

Overall, the interview partners repeatedly emphasized the importance of legislation, which underlines the importance of national governments and local authorities.

4.4.2 European Union

In addition to local authorities and national governments, the European Union is also playing a significant role in the energy sector, especially as the European markets are slowly merging. The role of the EU is significant in harmonizing the energy markets between its member states and encouraging the implementation of environmentally friendly technologies.

> “EU, of course, setting most of the legislation and trying to harmonize this area as well as bring or make it possible to add new or use new technologies that are cleaner.” -Interview partner 1

As the trend goes towards pan-European energy markets, the role of the EU is growing in the process. The decisions made in the EU have significant impacts on the European energy markets.

4.4.3 Energy companies

The energy producers were seen by the interview partners’ as important stakeholders as were different kinds of energy portfolio management companies and trading organizations. Naturally, electricity retails companies and distribution system operators were raised as important stakeholders in the industry as well.

> ” Of course, energy producers are in a key position, then different kinds of energy portfolio management companies, these kinds of trading organizations, of course, electricity retails companies are in the centre from the market participants perspective.” -Interview partner 2

> “…and then, of course, the operators of the electricity wholesale market.” - Interview partner 2

The role of network providers was emphasized during interviews. The increase of decentralised production is setting new requirements for the electricity grids, which will underline the importance of transmission system operators and distribution system operators.

> "From the basic infrastructure's point of view, the role of distribution system operators will stand out in a situation where decentralised resources are entering the market"-Interview partner 3

Overall, the decisions energy companies make and the directions they select have significant influence on the entire energy sector.

4.4.4 Information system service providers

Related to the development of technology it was also raised that the information technology service providers are playing a significant role in the industry through their services and innovations. They can be as well seen as important stakeholders in the energy sector.

> "IT service providers are also important stakeholders because nothing is today moving without IT solutions." -Interview partner 5

The role of information systems is emphasized as a large part of the processes are run by utilizing information systems. Provided information systems in general and significant development steps regarding them influence the entire energy industry.

4.4.5 Consumers

Many interview partners also discussed the importance of customers in general and particularly the importance of consumers. The interview partners saw that as customers' actions are affecting the market, they must be considered as an important stakeholder of the whole energy sector. Especially the role of consumers is growing, and there are going to be more active consumers acting as prosumers as well.

> "But then again, it is always the customers where it starts." -Interview partner 7

> " The role of customer, that was discussed earlier, how the role of the customer is growing." -Interview partner 3

Overall, the results show authorities and current operators in the energy sector as significant stakeholders of the industry. However, as the information systems, and energy generation solutions are developing rapidly, the role of information system providers and active consumers are increasing.

From the perspective of blockchain and smart contract systems, current market players are important stakeholders. Their decisions on desired technologies determine the direction industry is moving from an information systems perspective. If large companies would pursue extensive implementation of blockchain and smart contract systems in the energy sector, it would definitely create more interest in these technologies.

However, as the Finnish energy market is highly regulated, the role of governmental bodies and local authorities is significant. Introducing new technologies to the market requires that they are consistent with existing legislation or present substantial benefits that motivate changes to the regulations. The role of regulations and the existing system is discussed in the following chapter.

TABLE 6 The most important stakeholders in the energy sector

Code	**Percentage of observations (%)**	**Amount of observations (pcs)**
National Government & Local Authorities	71,4%	5
European Union	14,3%	1
Traders in electricity markets	42,9%	3
Producers	42,9%	3
Retailers	28,6%	2
Distribution System Operators	42,9%	3
Transmission System Operator	28,6%	2
Electricity Wholesale Market Operators	28,6%	2
Technology companies	28,6%	2
Consumers	42,9%	3

4.5 Regulations

This chapter is presenting the results regarding regulation related issues and possibilities for the introduction of blockchain and smart contract systems in the Finnish energy sector. These issues could be divided into legislative issues and the issues related to the existing system and its practices. These aspects are presented in Table 7.

4.5.1 Legislation

Issues or obstacles regarding current legislation were raised by five out of seven interview partners in the interviews as aspects that could block or forestall the implementation of blockchain technologies and smart contracts in the energy sector. In the Nordic countries, as the industry is highly regulated, the introduction of the presented new technologies would probably need changes to the legislation.

> "So, for example trying to get rid of the retailer or utility company by having some peer network. I find that kind of unlikely currently actually in the Nordics, due to legislative problems especially." -Interview partner 1

To be more specific about the presented issues, it was raised in the interviews that these aspects would probably concern metering legislative, verification legislative, and delivery chain legislative matters.

> "Preconditions are different kinds of legislative, metering legislative, verification legislative, and delivery chain legislative related. They would need to be handled in a different way, so it could be possible in the first place." -Interview partner 2

The problem regarding selling energy produced by solar panels was raised as one possible obstacle. Currently, producing electricity for selling purposes is not very motivating option for customers as the monetary benefits of it are relatively small.

> "There are tons of legislative problems and similar, for example, just an apartment building having solar panels and distributing the benefit of those is difficult." -Interview partner 1

From legislations perspective it was also mentioned that the introduction of new independent operators in the market could raise issues. During interviews it was emphasized that the roles in legislation need to be specified in a manner that will guarantee similar rights and responsibilities for old and new operators in the market.

> " …and the way how the entrance of independent aggregator to the market will be realized so that we can reach the goal of introducing more aggregated resources in the market while maintaining the markets open and undiscriminating. We need to specify the roles of different actors in legislation in a way that guarantees similar rights and responsibilities for operators which are doing similar activities." -Interview partner 4

However, it was also noted during the interviews that new legislation isn't necessarily always needed. In situations where legislation is blocking new solutions, this is naturally the case, but in some cases, existing legislation might allow new solutions for new technologies. In practice, this means that the development doesn't have to be in every case motivated by legislation changes.

> " I was thinking that do we always need official regulation for promoting things like this. Not necessarily. But if it is generally noted as a positive matter, so it could be advanced, but then there is some regulation which is preventing the development, then we might need to have that conversation with the authorities to promote the issue." -Interview partner 6

In highly regulated energy markets, like in Finland, the role of legislation is significant. Many reforms in the energy industry will require changes to the legislation as it is currently formed to serve the needs of existing system.

4.5.2 Existing system

Existing system is operating in close cooperation with current legislation. They are both dependent on each other. The dimensions of existing system together with existing legislation are relatively complex entirety, especially in the Nordic countries. If this wouldn't be the case, then implementing new solutions with novel technologies would be easier.

> " Definitely it could be used if we forget about all of the existing laws and regulations concerning the distribution business and electricity markets." - Interview partner 2

During interviews, it was also raised that blockchains nature as very disruptive technology would mean that the technological solution might at least partially replace existing operators. This would naturally mean a business risk for these operators at risk, which is why introducing this kind of technology to the industry or the legislation changes it would possibly need, would probably face extensive resistance.

> "But from business perspective these blockchains are very disruptive technology, so that in order to find ambition to change our whole system, it would mean that this technological solution would partially replace existing operators. And in the first place, large part of business models would cut off part of current operators from the value chain, and that is of course a business risk for these current operators." -Interview partner 2

> "So, then the benefit, possible benefit would need to be that either its more efficient than the current systems. Which means it'll replace current system types. Currently I see that a bit unlikely, especially with the hubs being

quite or seeming quite dominant or important currently, which is the like a, pretty far from blockchain type of thinking, so that's one really centralised system." -Interview partner 1

" But still if there is an existing system, then the benefit of will be marginal or non-existent or non-profitable to make the change at this point." -Interview partner 2

Interview partners also raised that the introduction of blockchain-based systems might cause changes that would go against the interest of current energy industry participants. Naturally, in these cases, reforms would possibly face resistance from these parties as they want to preserve their current market position.

"Here our current system works pretty well. That would go against the interests of quite a few fairly powerful parties and legislation would need to complete change, so I find it quite unlikely to happen on large scale in Europe in short time or short time period." Interview partner 1

"Possible benefit would need to be that either its more efficient than the current systems. Which means it'll replace current system types. Currently I see that a bit unlikely, especially with the hubs being quite or seeming quite dominant or important currently, which is like a, pretty far from blockchain type of thinking, so that's one really centralised system. But, perhaps further away in the future it's possible to make something that's more efficient or cost-efficient." -Interview partner 1

Blockchain technology would probably need an industry where there is distrust between the parties. Currently, in the Nordic electricity markets, the system is relatively well designed, which means that the benefits of blockchain-related solutions would be fairly limited.

" So, there should be significant distrust towards existing solutions, which are used in the electricity markets to motivate changes."-Interview partner 7

The results are showing that the current legislation in Finland and the practices of the existing system in the energy sector are creating substantial obstacles for the implementation of blockchain systems. The energy sector is highly regulated, which means that the possible changes would need to be evaluated from many perspectives and take many aspects into consideration. It would also mean that if new laws and regulation would be proposed, they would need thorough discussion about the matter before changes could be implemented.

As the current systems works relatively well, the implementation of blockchain systems would need convincing demonstration showing substantial improvements in efficiency comparing to existing system. Heretofore, substantial improvements in efficiency through implementation of blockchain systems have not been demonstrated in practice.

However, observed obstacles for the introduction of blockchain systems concerning regulation aspects might not cause problems for the introduction of smart contracts. This perspective was not thoroughly discussed during interviews, but smart contracts solutions that are not utilizing blockchain systems might not face similar issues. This aspect is an interesting avenue for future research.

Overall, blockchain systems should be able to present substantial benefits before laws and regulations could be changed to enable the introduction of blockchain systems technologies in the energy sector in larger scale. The introduction of blockchain systems might remove current market participants from the value chain. As a result, the change could face resistance from those parties who are losing their market position.

TABLE 7 Regulations related issues

Code	**Percentage of observations (%)**	**Amount of observations (pcs)**
Legislation	71,4%	5
Existing system	57,1%	4

4.6 Technology

This chapter is presenting the results of technology related opportunities and obstacles for the introduction of blockchain and smart contract systems in the Finnish energy sector. In total, 7 technology related aspects were observed from the data. They are presented in the Table 8.

4.6.1 Building trust

A large proportion of the utilization opportunities interview partners proposed were somehow related to the blockchain technology's ability to build trust between participants who might not have it between themselves in other circumstances. To be more precise, the trust is based on the blockchain technology in these situations. This aspect was raised by six out of seven interview partners (85,7%) and it was further discussed from many different perspectives.

> " Blockchains are useful when you need to run transactions between parties who don't have trust between them. So, in a way the trust is based on the blockchain." -Interview partner 4

As one of the main benefits of blockchain systems is their ability to build trust, it would have the most benefit in circumstances where there is a lack of trust otherwise. During interviews, it was raised that developing countries could have the biggest benefit in implementing blockchain systems as there are more issues concerning trust between market participants.

> “Emerging economics or, there I see quite a bit of potential use in both areas, whether that's handling a microgrid or energy retailer wanting to make sure that the consumer pays for the energy in the form of smart contracts so that energy is only released upon payment or something similar.” -Interview partner 1

In comparison, as described earlier in chapter 4.1.2 Nordic Energy sector, the Nordic energy markets were described as one of the most advanced. As the Nordic energy sector is highly regulated, there is little distrust between different participants. As a result, blockchain technology’s benefit in building trust would not offer same kind of improvement for Nordic energy markets as it would offer in the countries that have weaker systems.

4.6.2 Data storing

During the interviews it was also raised by two interview partners, that the blockchain is a very secure system in principle. This nature of technology could make it usable in the energy industry for data storing. Datahub would remove the middleman from the equation.

> “So, it (blockchain) is a very secure system. And it removes the middle-man from the equation in that accounting terminology.” -Interview partner 2

The main issue concerning data storing by utilizing blockchain technology would be the ongoing development and future deployment of datahub. The issue rises from datahubs design where information is stored in centralised fashion.

> ” The risk management perspective to data storing, which already came in that Datahub comment. So that is in my opinion something that could be that type, do we have to go towards it in the future.” Interview partner 5

However, during interviews it was raised that the introduction of centralised system like Datahub could be a risk from information security perspective. Utilizing blockchain technology in data storing was presented as one possibility to improve information security of data storing.

> ” But are we coming across with something that we should go for it for reducing the risk, so that in the future we would do something related to customer data with blockchain perspective, so we could reduce this risk. And

> this Datahub is one example which is centralizing all of the market data to one location. -Interview partner 5

The ongoing Datahub project is a major factor regarding utilization of blockchain systems in the energy sector. As the chosen solution is using centralised system for data storing, it currently seems implausible that the energy sector would change to decentralised system like blockchain in the near future. However, blockchain systems could be used for data storing in independent solutions.

4.6.3 Information security

The results also showed concern towards the information security of blockchain and smart contract solutions. Even though blockchain based solutions are often described as secure or even unbackable, few security issues have raised concerns towards the security of technology.

> "There haven't been many problems with blockchain I think, but for example Ethereum, which utilizes smart contracts has been hacked and as an emerging technology I find it personally quite likely that, if something like that is introduced there will likely be few problems, which could mess things a bit. That might lead to a bad name or such for the technology." -Interview partner 1

Otherwise, blockchain technology was described as interesting option from information security perspective.

> "Well, practically this solution (blockchain systems) does not have information security related risks, as this technology itself is very secure, because no one can interfere it." -Interview partner 2

Concerning smart contracts there could be issues regarding regulations like GDPR (General Data Protection Regulation), or standard regulations of the energy system. These are at least questions that needs to be investigated before presented solutions could be implemented.

> "Ton of problems I can see from that point-of-view, from privacy things like GDPR, how our energy system is regulated, so there's, if you produce energy and have contracts there's quite heavy legislation in that area." -Interview partner 1

Overall, the information security was described as one of the aspects that make blockchain interesting technology for the energy sector.

4.6.4 Performance and capacity

The questions and issues regarding the performance and capacity of blockchain technology was raised as one possible obstacle for the implementation of technology. As discussed, the performance issues could cause issues for the security of supply.

> ” Existing IT systems and their capacity need to be developed if, for example, the entire European electricity market is traded in small units.”-Interview partner 3

Interview partners were especially worried about the usage of blockchain technology in the large-scale trading where trading is done in small units. In these cases, it could be that the computing ability of blockchain based systems would not be enough for the requirements of the electricity market.

> ” The risks may be related to performance and capacity. So can the large-scale trading be done using blockchains utilizing small units. Will it have enough performance, especially if trading needs to be real-time. If it is wanted to use for real trading, then will the volume be enough.” -Interview partner 5

In addition to the concerns regarding the security of supply, it was also raised that the energy consumption of extensive blockchain solutions could have negative impacts to the environment. Large-scale trading requires high computing ability, which requires a lot of energy. This could mean that the blockchain based solution itself could be poor option for the environment from the perspective of energy efficiency.

> ” In very extensive use, a little dependent on how the technology used, the energy consumption of this technology, the requirements it sets for the capacity of processing to run these blockchains, different kinds of blockchains could have detrimental effects on environment.” -Interview partner 2

Interview partners described the issues regarding the performance and capacity as one of the most significant obstacles for the implementation of blockchain systems in the energy sector. If the blockchain system does not have enough capacity, the large-scale introduction of it could have precarious impacts concerning the security of supply.

4.6.5 Security of supply

The results showed that interview partners were concerned about how blockchain technology would affect the security of supply of energy. These concerns were raised in general level, fuelled by the unawareness of technology's ability to work in the actual market.

> " So then there would be challenges if these solutions cause difficulties regarding the security of supply. In that case, there would be large issues, because these current systems, which are related to current messaging practices, which is actively used for activations, but also for delivering metering data and so on." -Interview partner 7

In general level the security of supply was raised as an aspect that might decelerate the implementation process of blockchain technology and smart contracts in the energy sector. Before these technologies in question could be implemented, it would need to be thoroughly tested that they are not concerning any kind of issues from the supply security perspective.

> " It might be more about question of confidence, which are the things that can be trusted for the machine or system and which are not." -Interview partner 5

In general, the interview partners emphasized the importance of supply security. Questions related to it need answers before blockchain systems can be implemented in the energy sector.

4.6.6 Alternative technologies

In addition to the demonstrated possible obstacles for the implementation of blockchain technologies and smart contracts in the energy sector, it has to be remembered that there are always alternative solutions as well. One interview partner raised this aspect during the interviews as one possible obstacle for the implementation of proposed technologies.

> " And it needs to be remembered that there are alternatives for blockchain. That is a fact, because there are already different kinds of smart contracts in the electric markets, even on the retail level." -Interview partner 7

Alternative technologies mean that blockchain and smart contract systems need to demonstrate their superiority in comparison to other alternatives. From technology's perspective blockchain and smart contract systems could provide significant benefits for the energy industry. However, the issues regarding nature of technology and the performance capacity are reducing the realizable benefits of the technology. There are also technology related obstacles, which are connected to the Market dynamics in the Finnish energy sector. These aspects are discussed in the following chapter.

TABLE 8 Technology related opportunities and obstacles for blockchain and smart contract systems in the Finnish energy sector

Code	Percentage of observations (%)	Amount of observations (pcs)
Building trust	85,7%	6
Data storing	42,9%	3
Performance and capacity	42,9%	3
Security of supply	42,9%	3
Alternative technologies	14,3%	1
Information security	14,3%	1

4.7 Market dynamics

This chapter is presenting the results of market dynamics related opportunities and obstacles for the introduction of blockchain and smart contract systems in the Finnish energy sector. Total number of these observed aspects is 12. These are presented in the table 9.

4.7.1 Imbalance settlement

As presented in the chapter 4.1.3 Finnish energy sector, the utilization of imbalance settlement process where all consumption is settled based on metered hourly values instead of load curves was described by interviews partners as one of the main factors behind Finland's energy sector being one of the most advanced in Europe. The results are showing that the aspect of imbalance settlement is creating opportunities for blockchain and smart contract systems, but it also generates obstacles for the implementation of technologies in question.

> " This creates this kind of technological solution to change or to keep a record of things, without the need for trust towards separate parties which are keeping the record of it." -Interview partner 2

> " And in this case the question would concern the imbalance settlement, metering data gathering operations, this kind of things, where the blockchain could be exploited." -Interview partner 2

This kind of development was seen as interesting opportunity for the future, theoretically. Even though the idea could be practicable in theory, it doesn't mean it would be in the real world. In the case of imbalance settlements there are many obstacles. One of them is the nature of development where there would be no need for retail company anymore. In some scenarios this could be beneficial for the industry, but this kind of development would probably face a lot of resistance in the future. These kinds of aspects are further discussed later in the paper.

> " And then of course from imbalance settlement aspect, that when single consumers metering data would be inserted to this kind of blockchain for example, then the process would not necessarily need a separate retail company. Or like in this hypothetical situation there would be no need to have operator there in between to be able to make trades either with electricity you (consumer) have produced or with your consumption with other participants." -Interview partner 2

Results also showed that aspects of imbalance settlement process could be obstacles as well for the implementation of blockchain technologies in energy sector. It was raised by interview partners how central and essential imbalance settlement is in this entirety and how it is impossible to go around it. The imbalance settlement process is highlighted in the Figure 5.

> "And in electricity markets, it's necessary that we have there the imbalance settlement unit. In a way it not possible to go around the imbalance power unit, concerning for example selling energy through the electrical network. The imbalance power unit is there kind of forcibly, and it is the trusted party that handles it centralised. So then in a way, the benefits of blockchains are not achievable there." -Interview partner 4

This means that while blockchain technology could be used in the imbalance settlement process, the importance of the process in question for the energy markets is raising questions towards blockchain technology. These questions would need to be solved before the technology could be implemented to the energy markets processes.

> " We have this kind of hierarchical imbalance settlement. So how that blockchain would fit to it is the big question in my opinion." -Interview partner 3

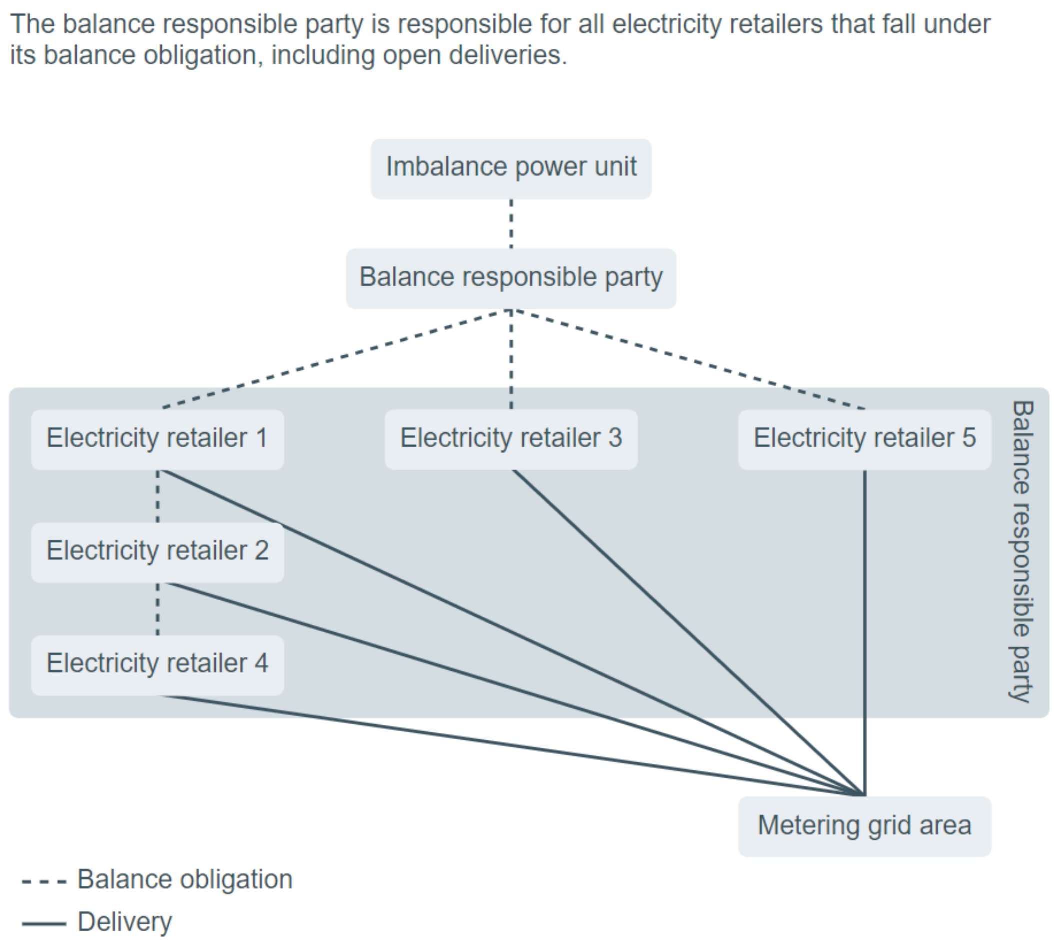

FIGURE 7 Imbalance settlement process (Fingrid, 2020a)

During interviews, it was also discussed whether current practices of imbalance settlement processes would enable the introduction of peer trading solutions. Especially, it was pondered how the system would work as the actual consumption would become evident afterwards.

> "So, if we would think that peer trading would enable that some actor would all the time trade all my consumption and acquire it. So how then it would be considered beforehand that how much I would, for some period of time, for example, fifteen minutes consume, when the real consumption becomes evident only afterwards. How it would be ensured that I would not acquire too much or too little? So how peer-to-peer trading would fit our imbalance settlement is the big question concerning these blockchain solutions."-Interview partner 3

Imbalance settlement processes are proposing challenges for alternative technologies as the hierarchy of it is one of the foundations of Finland's electricity system. As the system is highly trusted, the alternative technology would need to demonstrate substantial increase in efficiency, to justify the changes in technologies and processes. Highly automated solution utilizing blockchain and smart contract systems could provide the needed increase in efficiency.

4.7.2 Automation

Possibility for automating functions was raised by four interview partners during the interviews as one of the interesting aspects of blockchain and smart contract systems in the energy sector. Automation at some level is attached to other presented possibilities as well. In this case the opportunities regarding automation are the ones where actions currently made by people (customers in these examples) would be automated in the future by utilizing blockchain technology and smart contracts together, or one of them independently.

> "In the end, does end user need to do that push. What if there is some kind of deal made with integrator and then the integrator in the background changes electric vendors on the run." -Interview partner 6

Automation of processes utilizing technologies in question could mean that the technology acquires energy for customer based on set preconditions. In practice this could mean a situation where customer sets the preconditions which could be type of energy, type of production, accepted suppliers, and price for example. Then based on these preconditions and the market situation smart contract solution would automatically purchase energy for the customer.

> "If there are 50 000 end usage points and customers at that end and each of them have their own so called; A) For some it can be price emphasized, some value emphasized, some brand emphasized and everyone can themselves have an effect on it. But then there is the integrator in between, who is balancing between trading's between all of these and gathers marginal for itself as well. And in the end the end user who has given mandate to handle trading on their behalf based on these values or emphases." -Interview partner 6

However, during interviews it was pointed out that automating processes will generate more and more mistakes automatically if they happen.

> " … and automation has always a risk, that when you are doing thing automatically, then you are doing mistakes as well automatically."-Interview partner 5

For instance, if market operations for buying or selling would be handled automatically by smart contracts it could mean substantial monetary losses in the cases of system malfunction.

> "If we move to situation where purchasing operations or selling operations are done automatically, then it will mean that it cumulates to euros more sufficiently, and it cannot be fixed afterwards. If there is some automated function working incorrectly for a while in background process, then you can fix it manually. But when mistakes are done when moving money, then the fixes are trickier to do." -Interview partner 5

Overall, functionalities regarding automation of processes was emphasized as one of the most important benefits blockchain and smart contract systems can provide for the energy industry.

4.7.3 Peer-to-Peer network & Energy Communities

From the results we can see that many interview partners raised the aspects of peer-to-peer networks, energy communities and off grid solutions as potential pathways for blockchain technology development in the energy sector. In total, five out of seven interview partners (71,4%) raised at least one of these factors as central point of development for the technologies in question in the energy industry. One of the opportunities these technologies are offering, is removing the retail company out the equation in the cases regarding peer networks.

> "So, for example trying to get rid of retailer or utility company by having some peer network." -Interview partner 1

In the scope of Finnish energy sector these kind of off-grid solutions for peer networks could be beneficial due to amount of summer cottages, which can be located far away from existing grid. For these kinds of sites and areas the opportunity to create some sort of microgrid and energy community could be interesting.

> "Maybe there's some possibilities in for, in remote areas, say summer cottages or something, where they wouldn't need to be connected to the electricity grid at all." -Interview partner 1

> " It has been estimated that blockchain applications could be some kind of off grid solutions which are not connected to the grid."-Interview partner 3

Inside these communities' participants of it could do some sort of small-scale peer energy trading. Alternative for energy community could be internal energy company which could handle the trading inside a real property. The internal trading in these kinds of solutions could be managed utilizing blockchain and smart contract systems.

> "Or then for small scale peer trading. Whether it's some kind of energy community or internal energy company for real property, which we haven't

> discussed a lot. Where they sort of do the trading inside the property between themselves." -Interview partner 3

> " Then there are these differentiated microgrids, like energy community perspectives. If legislation and other matters would allow it, then these kinds of communities could theoretically trade energy between them or do energy business between themselves with their production and consumption. So, it would ensure its functionality with the micro grid, without having active operator in there between, but this kind of balancing of accounts could be done by this kind of technological solution." -Interview partner 2

It was proposed that presented solutions would have customer engagements in the background, with some kind of preconditions steering the operations. In practice it would mean that the operator of the community would acquire electricity depending on the situation, but doing decisions based on the set preconditions. Large part of the processes in presented solution could be handled by blockchain and smart contract systems.

> " So, for this kind of operator it might be a more relevant questions than to the single consumer. So, in a way, you have there in the background those customer engagements, so that I'm in this pool, so acquire what you see as the best option and in the best price you can get." -Interview partner 5

In practice, these solutions could be beneficial in neighbourhoods, where there are solar panels and wind farms facilitating small and local production.

> " One example could be a neighbourhood, where part of the people has solar panels, and part doesn't have them and there is nearby a small wind farm and this could work partly as some sort of microgrid. So, this kind of entirety that is separated from the electricity system. This kind of community could be called as energy community. Therefore, this kind of community could simply handle their own balance, their own accounting. Meaning who has consumed electricity, who has produced electricity and they don't need to have a separate operator in there between them as the technology will handle it." -Interview partner 2

In general, Peer-to-Peer networks were one of the concrete utilization possibilities that were repeatedly raised by the interview partners as interesting avenues to use blockchain and smart contract systems in the energy sector.

4.7.4 Demand response

The issue regarding demand response actions is one of the main topics in the energy industry concerning both, the present and the future. This issue was further demonstrated in the chapters presenting current state of the energy sector, emerging trends of it and the tension points in the energy sector.

The results of the empirical study are also showing that the blockchain technology and smart contracts are seen by the interview partners as possible solutions to mitigate the presented issue, which is constantly growing renewable and weather dependent energy sources are implemented.

> "Yes, so blockchain technology could be utilized for balancing production volumes and consumption volumes." -Interview partner 2

> "But there, definitely then ability to make or shift consumption and so on would be interesting and that would be interesting from the renewables point-of-view too." -Interview partner 1

The aspect of demand response is also related to the opportunities presented in earlier chapters. Especially opportunities concerning Peer-to-Peer trading and real time trading could be beneficial pathways of development from the demand response issues perspective as well.

> " Usually it has been said that blockchain would fit to this kind of peer trading and for application where electricity trading becomes closer to real-time and it is done in smaller units." -Interview partner 3

There have been few pilots introduced regarding the utilization of blockchain technology in this area. One of them, the pilot, which TenneT (Transmission system operator in the Netherlands and in Germany) have demonstrated, was raised in the interviews by one interview partner. TenneT have blockchain solutions in pilot projects in the Netherlands and Germany to facilitate flexible access to decentralised capacities.

> " So TenneT, which is a Dutch transmission system operator. So, they have sort of blockchain pilots, which are connected to the physical management of the national grid. So at least what I have understood, they are utilizing aggregated storages and this kind of loads. So, they are in a way buying flexibility from there and utilizing blockchain technology for it." -Interview partner 4

Interview partners emphasized the issue of demand response during interview process. Overcoming these issues is still an open question in the energy sector, and blockchain and smart contract systems offer interesting solutions for overcoming them.

4.7.5 Guarantees of origin

One possible avenue for blockchain technology development in the energy industry could be guarantees of origin. One interview partner raised this aspect. Guarantees of origin are sort of electric documents that are verifying how electricity has been produced (Klesmann et al., 2009). This is important aspect in the energy business as the usage of renewable energy sources is increasing and customers want to buy electricity that is produced by renewable energy sources.

> ” Guarantees of origin could be something where blockchain could work.”-Interview partner 3

> ” So, guarantees of origin are these kinds of electronic documents about the origin of electricity production. And it is separated from this physical side.”-Interview partner 3

In principle, this kind of development would mean that verification documents of production origin would be managed by blockchain. The benefit of the technology in this aspect would be its nature as trustworthy and unforgeable.

> ” So, then the producer will create those blocks and then they can be used to do business trustworthy and they cannot be forged, and one block can only be owned by one operator and so on. So, this guarantee of origin system could be interesting area where smart contracts and blockchain technology could be exploited.” -Interview partner 3

Guarantees of origin are managed separately from the energy trading, which means that it does not have similar concerns regarding performance and capacity. As a result, guarantees of origin could be managed by blockchain systems without changing practicalities or processes of energy trading.

4.7.6 Contracts

One important aspect of the market dynamics are the contracts and the ways they are managed. The results are showing that in the energy sector there are many opportunities for smart contracts in general. Currently there are solutions where smart contracts are used in the energy sector, which are not utilizing blockchain systems.

> ” Smart contracts are already utilized and, in the future, will be utilized in increasing matter.” -Interview partner 7

Whether these smart contract solutions use blockchain systems in the future is another question. Introducing these kinds of contracts to the market still has many open issues.

> "Is it used to establish certain kind of contracts, or is it used for trading, or is it used to deliver metering data… It has is upsides and downsides." -Interview partner 7

In practice, the utilization of blockchain, based smart contracts could provide a solution that would drop one party from the value chain. According to the results, that party would most likely be the retail company. In this situation it is unclear, that who would be the balance responsible party.

> "Then the second possible part would be, or benefit would be dropping one party from the value chain. In this case, the one that seems to make the most sense is the retail company." -Interview partner 1

Removing Retail Company from the value chain would change the whole energy trading process completely. In practice, it could mean the introduction of short-term contracts that are invoiced by the hour for example. This kind of development would be interesting from the energy community's perspective as well.

> "That would mean that the whole process changes completely, so then we would have possibly something like really short-term contracts as in hours or something, between producers and consumers, where the role of the consumer might vary depending on time and so on." -Interview partner 1

Introducing smart contracts to the retail side of electricity trading and energy markets in general would likely offer the biggest potential benefit because of number of contracts. During interviews, it was raised that in theory smart contracts could enable a situation where customer can change the electricity provider using smart phone.

> " Possibly the biggest benefit regarding number of contracts comes from private customers." -Interview partner 2

> "So, you could with your phone click that you change electricity contract from provider x to provider y. So, in this occasion it (blockchain based smart contract) would automatically handle the whole process." -Interview partner 2

However, interview partners also raised that smart contracts could be applied without dropping participants from the value chain.

> "Enabling some kind of new business without dropping retailer or some other company from in between. I guess similar thing could happen there except to make it easier you would always have the other side of the contract be that utility company, who is then able to verify things and so on."- Interview partner 1

In practice, the solution could include Retail Company playing the role of the expert in the market and making recommendations based on the market situation. In principle, Retail Company would buy electricity for the customer based on set preconditions.

> " Where energy company plays the role of the expert, makes recommendations based on market situation that what and when client should buy for the future. That is the first that comes to mind where (smart contracts) with certain precondition do trading as otherwise is done. Robots are doing it in normal stock market." -Interview partner 5

In practice customer could set preconditions regarding aspects like price, production type and time of consumption. Then based on these preconditions Retail Company would buy electricity for customer. These processes could be managed utilizing smart contracts.

> " So, with certain preconditions it could be possible to give parameters for managing the customer portfolio. Because the volume in single large-scale enterprise is large enough. And of course, if there are similar companies and these parameters can be bundle up together then they can be handled in larger pot and it will help it." -Interview partner 5

In theory, there are many interesting avenues in the energy sector for smart contract solutions. However, there in practice there are still many open questions and obstacles. One of them is the rigid nature of retail market, which is discussed in the following sub chapter.

4.7.7 Rigidity of the retail market

The results also showed concerns regarding how smart contracts could be used in retail markets because market is currently relatively rigid. The wholesale markets of electricity were seen from this perspective as a better option for smart contracts.

> " And especially if we start to collect verified and authenticated data from assets, then why it couldn't be used in wholesale markets as well." -Interview partner 2

> " It is possible to make offers based on smart contracts in electricity wholesale markets and in other businesses. But how it could be done on the retail side as it is currently quite rigid. And then the intelligence aspect comes with separate solutions, but it has to be referred that it has permissions and so on." -Interview partner 7

The results are showing that the greatest benefit from blockchain and smart contract systems could come from the retail markets. However, blockchain systems does not currently seem to possess enough performance and capacity to manage all of the market data.

Currently dynamics of the market seem to be formed in a way that is offering the best options for these technologies in different off-grid solutions that are not directly connected to the electricity grid. These could be peer-to-peer networks that are entirely off-grid solutions or connected to the grid through some kind of integrator. Other possible avenue for blockchain systems could be guarantees of origin as they are documents managed separately from market processes concerning trading.

TABLE 9 Market dynamics related opportunities and obstacles for blockchain and smart contract systems in the energy sector.

Code	**Percentage of observations (%)**	**Amount of observations (pcs)**
Imbalance settlement	42,9%	3
Automation	57,1%	4
Energy communities	57,1%	4
Peer-to-peer network	28,6%	2
Off grid solutions	28,6%	2
Real-time trading	28,6%	2
Demand response	28,6%	2
Utilizing aggregated storages	14,3%	1
Metering data gathering operations	14,3%	1
Guarantees of origin	14,3%	1
Contracts	57,1%	4
Rigidity of the retail market	14,3%	1

5 DISCUSSION

In this section, the results of the study are discussed and compared with earlier research. The results concluded to answer the research questions that were identified previously in this paper. Finally, the limitations of this study, its contributions, and suggestions for future research are discussed.

5.1 How can blockchain and smart contract systems be used in the energy sector?

The purpose of this study was to clarify the ways to utilize blockchain and smart contract systems in the energy industry. The research question was formed based on this research problem as:

- How can blockchain and smart contract systems be used in the energy industry?

The case in this study was the Finnish energy sector. The results show that the energy sector is in transformation as the introduction of datahub is moving all of the customer-related information to one place and unifying the practicalities in the industry. Simultaneously, the proportion of renewable energy sources is growing, and especially the implementations of wind and solar energy are increasing the weather dependency on energy production. As a result, the volatility in energy production is increasing and it affects the whole energy sector.

It is evident that the European Union wants to harmonize the legislation and regulations between European countries. Currently, national standards have substantial differences, and that together with problems in the infrastructure is causing obstacles for a higher level of integration between European countries.

Blockchain systems have been proposed as a solution to this issue. However, the results of this study show that current regulations and existing systems, especially in the Nordic countries are creating obstacles for the implementation of blockchain systems. As discussed in chapter 4.5 current legislation in the Nordic countries and Finland would need some changes before presented technologies could be introduced. The legislation is changeable, but in order to pursue those changes, blockchain systems would need to be able to show significant improvements in comparison to existing systems. The strengths and weaknesses as well as opportunities and threats for blockchain and smart contract systems in the Finnish energy sector are demonstrated utilizing SWOT analysis (Table 10).

According to Helms & Nixon (2010) SWOT analysis provides the foundation for the implementation of the desired alignment of organizational variables or issues. Listing favourable and unfavourable internal and external issues to the four quadrants of a SWOT analysis grid, planners, or researcher in this modification can better comprehend the avenues for leveraging strengths to realize new opportunities and understand the ways weaknesses can impede progress or magnify organizational threats. Additionally, by utilizing this form of analysis, it is possible to present ways for overcoming threats and weaknesses or develop future strategies. (Helms & Nixon, 2010). These aspects can be exploited in evaluating the design principles for blockchain and smart contracts in the Finnish energy sector.

TABLE 10 SWOT Analysis: Blockchain and smart contract systems in the Finnish energy sector

Strengths • Automation • Decentralised data storing • Information security • Building trust	Weaknesses • Performance and capacity
Opportunities • Peer-to-peer networks & Energy communities • Guarantees of origin • Data storing	Threats • Existing system • Rigidity of the retail market

The existing systems in Finland and other Nordic countries are relatively advanced and highly regulated. The results are also showing that there are no significant trust issues between different participants in the energy markets. This aspect might be an obstacle for blockchain systems as one of its main benefits is that it can build trust in a situation where there would be a lack of trust otherwise. As a result, it seems that Nordic countries, including Finland, are from this perspective the countries with the least benefits from introducing blockchain systems to their energy industry on a large scale. The large-scale implementation of blockchain systems would also require development for the performance and capacity of blockchain systems.

The results show that blockchain systems do not currently possess enough performance and capacity to process trading information in the energy markets. As the goal is to move towards real-time trading and towards smaller electricity trading units, the requirements for information processing capacity are growing in the process. Presented issues could cause a problem concerning the security of supply as well. However, these observations were made concerning the whole energy markets, so capacity and performance might not be an issue for solutions that are only handling the energy market's activities or processes not directly linked to the current processes.

Presented development could be achievable in different off-grid solutions. Besides, different kinds of peer-to-peer networks and energy communities could utilize blockchain systems without facing the same issues that large-scale implementation would face. Energy communities could use peer-to-peer networks.

These networks could be entirely off-grid solutions or connected to the electricity grid.

Neighbourhoods could form energy communities for example. Participants of the energy community could act there as a prosumer or consumer. Prosumers are producing electricity utilizing solar panels, for instance, and selling their surplus energy to their neighbours who are part of the energy community. This type of trading could prove to be wearing if it would require recurring actions from participants.

Blockchain and smart contract systems could provide a solution for the automation of processes and data storing. In principle, the surplus energy of prosumers would be sold to participants of the energy community based on set preconditions. The whole process would be automated utilizing blockchain and smart contract systems. In this solution, the data would be stored in the blockchain. The presented solution could operate on its own as an off-grid solution.

However, it is likely that in many cases, the energy production capacity of these communities would not be enough. In these cases, there would be a need for an integrator, which job would be to balance the production and consumption of the energy community by purchasing electricity from retail companies, for example. The Peer-to-Peer energy community model is illustrated in figure 8.

In the presented model, participants of the energy community can act as traditional consumers or prosumers who produce electricity by solar panels or small wind farms, for instance. The electricity trading inside the energy community is conducted by utilizing blockchain and smart contract systems. The arrows in the figure below illustrate the flow of electricity and money inside the energy community. The role of the integrator is to ensure that the energy generation and consumption levels are balanced inside the community. If the energy generation levels of the community exceed its consumption levels and capacity to retain energy, then integrator could sell the surplus in the energy markets. Although, this solution would require that the grid has the capacity to receive the surplus energy from energy communities.

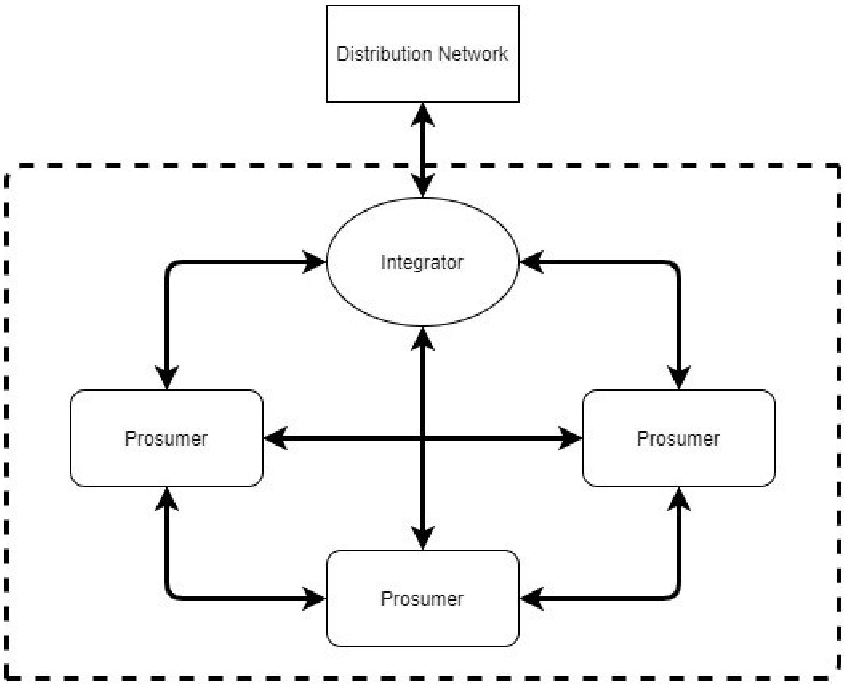

FIGURE 8 Peer-to-Peer Energy Community Trading Model

Even if energy production capacities in the energy communities would be large enough to respond to consumption levels inside them, the energy communities could face challenges during peak demand hours. In the presented situation, this kind of integrator would be beneficial as well, assuming that retaining energy remains as challenging as it is today. Currently, demand response management is managed by the electricity markets.

In theory, blockchain and smart contract systems could offer solutions concerning demand response. Blockchain and smart contract systems' ability to automate processes could help to balance the levels of production and consumption. Currently, the prices in the energy markets are handling the balance, but as the production is moving towards more weather-dependent energy sources it could mean that the markets with current processes cannot react quickly enough.

Moving to closer trading units and towards real-time trading is going to increase the agility of the market to balance the levels of production and consumption. As trading moves to closer units, the amount of trading is increasing as well, which in hand increases the need for automating processes. Blockchain and smart contract systems could offer solutions for these processes, but as presented, they do not possess the capacity to do it on a larger scale, processing a large number of trading processes in a minute.

Even though performance and capacity issues are setting obstacles for the large-scale implementation of blockchain systems in the energy sector, the technology could still be exploited in distinct solutions that are not tightly connected to the trading processes. Guarantees of origin is this kind of distinct solution, and as presented in the results section, it could be an area where blockchain systems could be utilized. The growing number of renewable energy sources and the growing number of small production and prosumers is creating a need for a more efficient system for managing guarantees of origin related verification documents. Blockchain systems distributed ledgers would be an interesting option for managing these documents they cannot be interfered with.

The obstacles for the introduction of blockchain systems in the energy sector might not prevent large utilization of smart contracts. As discussed in the results section, smart contracts are already in use in the energy sector. A large part of the presented solutions including blockchain systems could be managed utilizing smart contracts with other data storing options. However, the larger scale utilization of them would require the development of technology and research on how it can adapt to the needs of the highly regulated industry. For instance, how smart contracts could be utilized in the energy retail market that is quite rigid currently.

5.2 Contribution

This chapter presents the contributions this study has to the blockchain and smart contract systems utilization in the Finnish energy sector. As the topic is relatively new and there are not a lot of research made about it, the objective was to conduct exploratory research.

The chosen analysis method of the conventional approach to content analysis was suitable as it offers an avenue to gain direct information from interview partners without imposing preconceived categories or theoretical perspectives. The knowledge gained from the content analysis is based on interview partners' unique perspectives and grounded in the actual data (Hsieh & Shannon, 2005).

This study has demonstrated different ways blockchain and smart contract systems could be utilized in the Finnish energy sector, and what different solutions would require. The model of the Peer-to-Peer energy community trading model is presented to demonstrate a concrete utilizing option for blockchain and smart contract systems in the Finnish energy sector.

The study is presenting the strengths and weaknesses of the blockchain and smart contract systems have for succeeding in the Finnish energy sector. The study is also discussing the opportunities and threats for the utilization of these technologies in question in the energy industry.

Based on the study it seems improbable that the Finnish energy sector would implement blockchain systems in near future. However, the study demonstrates alternative ways for blockchain systems utilization in the energy sector. These are different kinds of peer-to-peer networks and novel solutions for managing guarantees of origin.

The study is demonstrating many avenues for the utilization of blockchain systems. However, many of these avenues require further research that focuses on the specific subject in question. The pilot projects elsewhere have demonstrated the difficulties of introducing blockchain-based systems to an industry that is highly regulated with complicated current systems and processes.

Even though this research has presented significant obstacles for the introduction of blockchain and smart contract systems in the Finnish energy sector that does not mean they are not recommendable areas of research. Blockchains and smart contracts are promising technologies that the energy sector should carefully monitor and proactively develop.

5.3 Limitation

This chapter is presenting the limitations of this study. Identified limitations were related to the data set, earlier research, researcher, the scope of the study, and study methods, which might affect the credibility and generalizability of the study.

The number of interview partners that would be relevant for the study was limited, as there is a restricted amount of people that would have extensive knowledge regarding the energy sector and the technologies in question. Despite this, research had enough interview partners considering its qualitative nature (Hirsjärvi & Hurme, 2008). The objective was to have interview partners from various organizations, including electricity companies, information system providers, and professional organizations.

The data set of qualitative research may affect how results can be generalized. According to Hirsjärvi & Hurme (2008), the difference between groups and statistical generalization cannot be done if the number of interview partners is small. However, they are arguing that the research data content may be extensive, and it can provide remarkable information about the phenomenon even with few interviews (Hirsjärvi & Hurme, 2008)

This study is a qualitative interview study and the objective of it is to discover new information regarding the research subject. As a result, the amount of interview partners is not a significant limitation for the study (Hirsjärvi & Hurme, 2008). The interview partners were chosen based on certain criteria. The objective was to engage persons, who are working in the Finnish energy industry and have sufficient knowledge about blockchain and smart contract systems. Some interview partners had extensive knowledge only about the industry, and only a sufficient amount of knowledge concerning blockchain and smart contract systems, which can be seen as a limitation for the study. Presented sampling was used to reach the best candidates for the research. The chosen research method was an empirical qualitative half-structured interview study. The method in question was seen as suitable for a topic that has a limited amount of earlier research. This can raise the credibility of the study.

From the literature review's perspective, the limited amount of literature concerning blockchain and smart contract systems in the Finnish energy sector is one limitation of the study. Technologies in question have a lot of recent research, but how large part of them have been focusing on pilot projects elsewhere. These pilots provide useful information for the Finnish energy sector as well, but the demonstrated differences in the energy sector practices, processes, and regulations between the countries create demands for country specific research. Regarding the Finnish energy sector, there are few studies made from the energy sector perspective, but the amount of scientific publications is limited. However, there was enough literature about the technologies in question and the Finnish energy sector to apply them together in an exploratory style.

Concerning researcher, experience, personal views, and competence can be seen as limitations for the study. This master's thesis is the researchers' first empirical study and the lack of experience can be seen as a limitation for the study. In addition, researchers' personal views and interests towards the researched subject might reduce the reliability of the study, but this aspect has been considered in advance, and reduce the influence of it. Researchers' competence in empirical studies can be seen as a limitation for the study and it can reduce the reliability and credibility of the study. This limitation significance was reduced by consulting the supervisor of this study and by reading methodology literature in order to improve the reliability of the study.

The scope of the study might be a limitation of this study as the context of the Finnish energy sector is setting impediments for generalizing the study to a more international context. Few interview partners represented international organizations, but that is not covering the international context by itself as the study otherwise is focused on the Finnish energy sector. This aspect can be seen as a limitation of the study from the perspective of generalizability.

The chosen analysis method could be a limitation for the study as conventional content analysis may fail to develop a complete understanding of the context, thus failing to identify key categories. As a result, the findings might not accurately represent the data. (Hsieh & Shannon, 2005.) Another challenge for this method is that it is easily confused with other qualitative methods such as the grounded theory method (GTM). These methods share a similar initial analysis approach, but GTM goes beyond content analysis in order to develop theories or a nuanced understanding concerning the lived experience. According to Hsieh & Shannon (2005), the conventional approach to content analysis is limited from the perspectives of theory development and the ability to describe lived experience. The reason for this lies in sampling and analysis procedures, which make it difficult to infer from findings the theoretical relationship between concepts. (Hsieh & Shannon, 2005)

5.4 Future Research

In this chapter are presented the suggestions for future research. The proposed future research topics relate to the results and the observations that were not profoundly investigated during this study. Interview partners raised part of the presented topics for future research during the interview process. These are included in the proposals as well.

During the interview process, it was raised by two interview partners that blockchain and smart contract systems could provide substantial benefits for emerging economies, as there is a lack of trust between the market parties and blockchain systems could provide a solution for that issue.

> “Maybe that'll happen even in some emergent economics like in Africa or some other areas, especially in more remote societies, or places where it’s difficult to trust the participants.” -Interview partner 1

In emerging economies, there usually is not a highly regulated and trusted system, so at least in theory new system could be designed from scratch. In these situations, blockchain-based systems could provide to be the best solution as there are no existing regulations and processes that would need to be changed to fit blockchain-based solution. In principle, basic activities like imbalance settlement and consumption accounting could be managed by blockchain systems.

> ” The most essential benefit of blockchain comes in the context where there isn’t an existing system that works, which has trustworthy operators in a central role to facilitate the functioning of electricity markets. Therefore, in these cases, we can take this sort of blank slate model, where we could establish electricity markets in principal for the first time to some developing markets, which does not necessarily have standardized, trustworthy, and concentrated operators. So, on these occasions, blockchains offer great possibilities to create the basic foundations for activities, imbalance settlement, consumption accounting, and these kinds of things.” -Interview partner 2

Utilization opportunities in emerging economies would be one interesting avenue for future research, as the nature of blockchain technology would provide there probably a larger benefit than in areas with highly regulated and relatively well-functioning energy systems.

In the areas where energy systems are highly regulated, different kinds of Peer-to-Peer networks have been a topic of interest. However, from the Finnish energy sector perspective, this opportunity is relatively lesser researched, which is why Peer-to-Peer networks, utilizing blockchain systems or not, would be an interesting research topic from the Finnish energy sectors perspective.

Regarding these Peer-to-Peer networks, the relationship between blockchain-based Peer-to-Peer networks and smart home appliances would be an interesting topic of discussion, especially from the perspective of energy consumption balancing. In principle, the energy consumption in smart homes could be adapted to the market situation in a solution where automatic systems buy electricity when the price is low and smart home appliances consume electricity based on the market situation. The presented solution would be an interesting solution from the demand response perspective as well, because it would probably automatically balance the consumption levels in households and level of energy usage peaks as the systems would automatically lower the energy consumption when the price is higher. This solution might not be implemented utilizing blockchain systems, but it would require a high level of automation, which could be managed by blockchain and smart contract systems.

In addition to Peer-to-Peer network solutions, the utilization and deployment-related aspects concerning smart contracts in the energy sector would be an interesting topic for future research. As mentioned earlier, certain kinds of smart contracts are already utilized in the energy sector, but they have not been implemented on a larger scale.

Regarding smart contracts, their legal aspects would be an interesting topic of research as well. If smart contracts would be used in extensive scope for electricity trading, then how would it be managed from the legislations' perspective? The responsibilities in the events of malfunctions would be an interesting topic, as it is unclear who would have to take the responsibility if smart contracts are conducting mistakes in their trading activities.

6 CONCLUSION

This chapter is summarizing the conclusions of this Masters' Thesis. The research objective of the thesis was to investigate how blockchain and smart contract systems could be utilized in the Finnish energy sector. To assess this research question, this study defined blockchain and smart contract systems, the ways energy providers are currently managing contracts, and the business and technology-related requirements for blockchain and smart contracts in the Finnish energy market.

This Masters' Thesis included a literature review and an empirical case study that was conducted using semi-structured interviews as a study method. The literature review created a theoretical foundation for the empirical part of the study. The literature review is presented in chapter 2. Chapter 2.1 presents the situations of the energy industries in Europe, Nordic countries, and Finland. Chapter 2.2 presents the concept of smart grids and how it is related to this research. Chapter 2.3 defines blockchain and smart contract systems as a term and technology and demonstrates how they have been proposed to utilize in the energy sector. Chapter 2.4 summarizes the literature review. After the literature review, empirical research is presented in chapters 3-5. Chapter 3 presents the research methodology including descriptions of data collection, data set, and data analysis. The results of empirical research are presented in chapter 4 and discussed in chapter 5. The conclusion of this Masters' Thesis is presented in chapter 6.

The conclusion of this study indicates that the actions to reduce carbon emissions are creating new challenges for the energy industry as the increasing amount of renewable energy is increasing the weather-dependency and the volatility in the energy markets. Blockchain and smart contract systems have been presented as a solution for many issues in the energy sector and pilot projects around the world have given promising results concerning their utilization in the energy sector.

However, implementations of these technologies on a larger scale do not seem to happen in the near future. Blockchain and smart contract systems have yet to demonstrate substantial benefits for the highly developed and highly regulated energy markets. Due to this aspect, it is unlikely that these technologies would be implemented on a large scale in countries that have well-functioning and highly regulated energy markets, like Finland. However, blockchain and smart contract systems are promising technologies offering interesting solutions that the energy sector should closely monitor and proactively develop.

REFERENCES

Alam, M. R., St-Hilaire, M., & Kunz, T. (2017). An optimal P2P energy trading model for smart homes in the smart grid. *Energy Efficiency, 10(6),* 1475-1493.

Battaglini, A., Lilliestam, J., Haas, A., & Patt, A. (2009). Development of SuperSmart Grids for a more efficient utilisation of electricity from renewable sources. *Journal of cleaner production, 17*(10), 911-918.

Beato, P., & Fuente, C. (1999). *Retail Competition in Electricity*. Inter-American Development Bank, Sustainable Development Department, Infrastructure and Financial Markets Division.

Bhattacherjee, A. (2012). Social science research: Principles, methods, and practices.

Blom, F. (2018). A Feasibility Study of Blockchain Technology as Local Energy Market Infrastructure (Master's thesis, NTNU).

Bocquillon, P., & Maltby, T. (2017). The more the merrier? Assessing the impact of enlargement on EU performance in energy and climate change policies. *East European Politics, 33*(1), 88-105.

Botsman, R., & Rogers, R. (2010). Beyond zipcar: Collaborative consumption. Harvard Business Review, 88(10), 30.

Bremdal, B. A., Olivella, P., & Rajasekharan, J. (2017). EMPOWER: A network market approach for local energy trade. In *2017 IEEE Manchester PowerTech* (pp. 1-6). IEEE.

Bremdal, B. A., Olivella-Rosell, P., Rajasekharan, J., & Ilieva, I. (2017). Creating a local energy market. *CIRED-Open Access Proceedings Journal, 2017(1)*, 2649-2652

Buterin, V. (2014). A next-generation smart contract and decentralized application platform. *white paper, 3*(37).

Child, M., Kemfert, C., Bogdanov, D., & Breyer, C. (2019). Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe. *Renewable Energy, 139*, 80-101.

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the internet of things. *Ieee Access, 4*, 2292-2303.

Clastres, C. (2011). Smart grids: Another step towards competition, energy security and climate change objectives. *Energy policy, 39*(9), 5399-5408.

CRE (2019). Wholesale electricity market. Retrieved 13th November 2020 from https://www.cre.fr/en/Electricity/Wholesale-electricity-market/wholesale-electricity-market

Cross, S., Hast, A., Kuhi-Thalfeldt, R., Syri, S., Streimikiene, D., & Denina, A. (2015). Progress in renewable electricity in Northern Europe towards EU 2020 targets. *Renewable and Sustainable Energy Reviews, 52*, 1768-1780.

Delmolino, K., Arnett, M., Kosba, A., Miller, A., & Shi, E. (2016, February). Step by step towards creating a safe smart contract: Lessons and insights from a cryptocurrency lab. In *International conference on financial cryptography and data security* (pp. 79-94). Springer, Berlin, Heidelberg.

Ediel (2020). The Datahub project - towards centralised information exchange. Retrieved 16th October 2020 from https://www.ediel.fi/en/datahub

Edso (2020). Why Smart grids? Retrieved 13th November 2020 from https://www.edsoforsmartgrids.eu/home/why-smart-grids/

Energiateollisuus (2016). Sähkömarkkina- ja verkkovisio 2035 & Roadmap 2025. Retrieved 12th November 2020 from https://energia.fi/files/786/Roadmap_2025_loppuraportti.pdf

EntsoE Event (2020). Transmission System Operator. Retrieved 13th November 2020 from http://www.entsoe-event.eu/transmission_system_operator.html

European Commission (2017). European Commission, Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, 2017.

European Commission (2020). 2030 Climate & Energy Framework. Retrieved 6th February 2020 from https://ec.europa.eu/clima/policies/strategies/2030_en

Farhangi, H. (2009). The path of the smart grid. *IEEE power and energy magazine*, 8(1), 18-28.

Fingrid & TEM, (2018). Lohkoketju osana älykästä sähköjärjestelmää. Retrieved 16th October 2020 from https://tem.fi/documents/1410877/3481825/Lohkoketjuteknologia+osana+%C3%A4lyk%C3%A4st%C3%A4+s%C3%A4hk%C3%B6j%C3%A4rjestelm%C3%A4%C3%A4+28.8.2018/752904f3-a765-443a-b3d0-6947999c1a68/Lohkoketjuteknologia+osana+%C3%A4lyk%C3%A4st%C3%A4+s%C3%A4hk%C3%B6j%C3%A4rjestelm%C3%A4%C3%A4+28.8.2018.pdf

Fingrid (2018). Annual Report – Electricity Markets. Retrieved 5th February 2020 from https://annualreport.fingrid.fi/en/business-operations/electricity-market.html

Fingrid (2020a). Imbalance Settlement. Retrieved 7th November 2020 from https://www.fingrid.fi/en/electricity-market/balance-service/imbalance-settlement/

Fingrid (2020b). Varttitase eli 15 minuutin taseselvitysjakso. Retrieved 15th November 2020 from https://www.fingrid.fi/sahkomarkkinat/markkinoiden-yhtenaisyys/sahkomarkkinoiden-kehityshankkeet/varttitase/

Fingrid (2020c). Datahub Go-Live date to be postponed to 2022. Retrieved 10th November 2020 from https://www.fingrid.fi/en/pages/news/news/2019/datahub-go-live-date-to-be-postponed-to-2022/

Fingrid Datahub Oy, (2019). Electricity retail market business processes in Datahub (version 1.10) [electrical data] Retrieved 2nd November 2019 from https://www.ediel.fi/en/datahub/business-processes/documentation

Fingridlehti (2018). Planning for implementation of 15-minute imbalance settlement has started. Retrieved 5th February 2020 from https://www.fingridlehti.fi/en/planning-implementation-15-minute-imbalance-settlement-started/

Fingridlehti (2018). Sähköautot, uhka vai mahdollisuus? Retrieveed 15th November 2020 from https://www.fingridlehti.fi/sahkoautot-uhka-vai-mahdollisuus/

Finnish Energy (2019). Energy year 2018 – Electricity. Retrieved 30th October 2020 from https://energia.fi/en/newsroom/publications/energy_year_2018_-_electricity.html#material-view

Fridolfsson, S. O., & Tangerås, T. P. (2009). Market power in the Nordic electricity wholesale market: A survey of the empirical evidence. *Energy Policy, 37*(9), 3681-3692.

Gao, J., Asamoah, K. O., Sifah, E. B., Smahi, A., Xia, Q., Xia, H., ... & Dong, G. (2018). Gridmonitoring: Secured sovereign blockchain based monitoring on smart grid. *IEEE Access, 6*, 9917-9925.

Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. (2011). Smart grid technologies: Communication technologies and standards. *IEEE transactions on Industrial informatics, 7*(4), 529-539.

Haber, S., & Stornetta, W. S. (1990, August). How to time-stamp a digital document. *In Conference on the Theory and Application of Cryptography* (pp. 437-455). Springer, Berlin, Heidelberg.

Hahn, A., Singh, R., Liu, C. C., & Chen, S. (2017, April). Smart contract-based campus demonstration of decentralized transactive energy auctions. In *2017 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)* (pp. 1-5). IEEE.

Hamari, J., Sjöklint, M., & Ukkonen, A. (2016). The sharing economy: Why people participate in collaborative consumption. *Journal of the association for information science and technology, 67(9)*, 2047-2059.

Hao, X., Wang, Y., Wu, C., Wang, A. Y., Song, L., Hu, C., & Yu, L. (2012, November). Smart meter deployment optimization for efficient electrical appliance state monitoring. In *2012 IEEE Third International Conference on Smart Grid Communications (SmartGridComm)* (pp. 25-30). IEEE.

Hasse, F., Von Perfall, A., Hillebrand, T., Smole, E., Lay, L., & Charlet, M. (2016). Blockchain–an opportunity for energy producers and consumers. *PwC global power & utilities*, 1-45.

Helms, M. M., & Nixon, J. (2010). Exploring SWOT analysis–where are we now?. *Journal of strategy and management*.

Henley, J. (2019, 4th June) Finland pledges to become carbon neutral by 2035. Retrieved 4th February 2020 from https://www.theguardian.com/world/2019/jun/04/finland-pledges-to-become-carbon-neutral-by-2035

Hiekka, T. (2019). Guidelines for Implementing Common Information Model in Electricity Retail Market Information Exchange.

Hirsjärvi, S., & Hurme, H. (2008). *Tutkimushaastattelu: teemahaastattelun teoria ja käytäntö Sirkka Hirsjärvi & Helena Hurme.* Gaudeamus Helsinki University Press.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288.

Huh, S., Cho, S., & Kim, S. (2017, February). Managing IoT devices using blockchain platform. In *2017 19th international conference on advanced communication technology (ICACT)* (pp. 464-467). IEEE.

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. *Harvard Business Review, 95*(1), 119-127.

Jääskeläinen, J., Lager, J., & Syri, S. (2019, September). Development of Energy Security in Finland and in the Baltic States since 1991. In *2019 16th International Conference on the European Energy Market (EEM)* (pp. 1-6). IEEE.

Jääskeläinen, J., Veijalainen, N., Syri, S., Marttunen, M., & Zakeri, B. (2018). Energy security impacts of a severe drought on the future Finnish energy system. *Journal of environmental management, 217*, 542-554.

Jääskeläinen, J., Zakeri, B., & Syri, S. (2017, June). Adequacy of power capacity during winter peaks in Finland. In *2017 14th International Conference on the European Energy Market (EEM)* (pp. 1-6). IEEE.

Järventausta, P., Verho, P., Partanen, J., & Kronman, D. (2011, June). Finnish smart grids—a migration from version one to the next generation. In *21st international conference on electricity distribution. CIRED, Frankfurt.*

Kabalci, Y. (2016). A survey on smart metering and smart grid communication. *Renewable and Sustainable Energy Reviews, 57*, 302-318.

Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of Social Media. *Business horizons, 53(*1), 59-68.

Khodadadi, A., Herre, L., Shinde, P., Eriksson, R., Söder, L., & Amelin, M. (2020, September). Nordic Balancing Markets: Overview of Market Rules. In *2020 17th International Conference on the European Energy Market (EEM)* (pp. 1-6). IEEE.

Khosravi, A., Olkkonen, V., Farsaei, A., & Syri, S. (2020). Replacing hard coal with wind and nuclear power in Finland-impacts on electricity and district heating markets. *Energy, 203*, 117884.

Kim, G., Park, J., & Ryou, J. (2018, January). A study on utilization of blockchain for electricity trading in microgrid. In *2018 IEEE International Conference on Big Data and Smart Computing (BigComp)* (pp. 743-746). IEEE.

Klessmann, C., Ensslin, C., Ragwitz, M., & Resch, G. (2007). European renewable energy trade based on Guarantees of Origin (GOs)–concepts, critical issues, and recommendations for design. *A paper within the research project "Wissenschaftliche und fachliche Unterstützung des BMU bei der Diskussion der Fortentwicklung der EU Politik zur Förderung der Erneuerbaren Energien "(FKZ UM07 41 604) of the German Federal Ministry for the Environment (BMU). Ecofys.*

Kondracki, N. L., Wellman, N. S., & Amundson, D. R. (2002). Content analysis: Review of methods and their applications in nutrition education. *Journal of nutrition education and behavior, 34*(4), 224-230.

Kosba, A., Miller, A., Shi, E., Wen, Z., & Papamanthou, C. (2016, May). Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In *2016 IEEE symposium on security and privacy (SP)* (pp. 839-858). IEEE.

Kumpulainen, L., Kauhaniemi, K., Repo, S., Valkealahti, S., Honkapuro, S., Partanen, J., ... & Jarventausta, P. (2016). Roadmap towards the vision of the future power system and electricity market.

Lauslahti, K., Mattila, J., & Seppälä, T. (2016). *Älykäs sopimus: Miten blockchain muuttaa sopimuskäytäntöjä?* (No. 57). ETLA Report.

Liu, N., Yu, X., Wang, C., Li, C., Ma, L., & Lei, J. (2017). Energy-sharing model with price-based demand response for microgrids of peer-to-peer prosumers. *IEEE Transactions on Power Systems, 32*(5), 3569-3583.

Liu, T., Tan, X., Sun, B., Wu, Y., Guan, X., & Tsang, D. H. (2015, November). Energy management of cooperative microgrids with p2p energy sharing in distribution networks. In *2015 IEEE international conference on smart grid communications (SmartGridComm)* (pp. 410-415). IEEE.

Longhurst, R. (2003). Semi-structured interviews and focus groups. *Key methods in geography, 3*(2), 143-156.

Ma, Z., Prljaca, Z., & Jørgensen, B. N. (2016, June). The international electricity market infrastructure-insight from the nordic electricity market. In *2016 13th international conference on the European energy market (EEM)* (pp. 1-5). IEEE.

Maciejowska, K., Nitka, W., & Weron, T. (2019). Day-ahead vs. Intraday—Forecasting the price spread to maximize economic benefits. *Energies, 12*(4), 631.

Mannaro, K., Pinna, A., & Marchesi, M. (2017, September). Crypto-trading: Blockchain-oriented energy market. In *2017 AEIT International Annual Conference* (pp. 1-5). IEEE.

Mengelkamp, E., Notheisen, B., Beer, C., Dauer, D., & Weinhardt, C. (2018). A blockchain-based smart grid: towards sustainable local energy markets. *Computer Science-Research and Development, 33*(1-2), 207-214.

Mihaylov, M., Jurado, S., Avellana, N., Van Moffaert, K., de Abril, I. M., & Nowé, A. (2014, May). NRGcoin: Virtual currency for trading of renewable energy in smart grids. In *11th International conference on the European energy market (EEM14)* (pp. 1-6). IEEE.

Monacchi, A., & Elmenreich, W. (2016). Assisted energy management in smart microgrids. *Journal of Ambient Intelligence and Humanized Computing, 7*(6), 901-913.

Motalleb, M., & Ghorbani, R. (2017). Non-cooperative game-theoretic model of demand response aggregator competition for selling stored energy in storage devices. *Applied Energy, 202*, 581-596.

Mourshed, M., Robert, S., Ranalli, A., Messervey, T., Reforgiato, D., Contreau, R., ... & Lennard, Z. (2015). Smart grid futures: Perspectives on the integration of energy and ICT services. *Energy Procedia, 75*, 1132-1137.

Münsing, E., Mather, J., & Moura, S. (2017, August). Blockchains for decentralized optimization of energy resources in microgrid networks. In *2017 IEEE conference on control technology and applications (CCTA)* (pp. 2164-2171). IEEE.

Mylrea, M., & Gourisetti, S. N. G. (2017, September). Blockchain for smart grid resilience: Exchanging distributed energy at speed, scale and security. In *2017 Resilience Week (RWS)* (pp. 18-23). IEEE.

Narayanan, A., Bonneau, J., Felten, E., Miller, A., & Goldfeder, S. (2016). *Bitcoin and cryptocurrency technologies: a comprehensive introduction.* Princeton University Press.

Nordic Balancing Model (2019). The Nordic TSOs confirm the need for longer implementation time of 15 minutes imbalance settlement period. Retrieved 15th November 2020 from https://nordicbalancingmodel.net/the-nordic-tsos-confirm-the-need-for-longer-implementation-time-of-15-minutes-imbalance-settlement-period/

Nordic Balancing Model (2020a). 15 Minutes Time Resolution (FAQ). Retrieved 5th February 2020 from http://nordicbalancingmodel.net/15-minutes-time-resolution/

Nordic Balancing Model (2020b). What is Nordic Balancing model?. Retrieved 5th February 2020 from https://nordicbalancingmodel.net/about/

Nordic Council of Ministers (2017). Nordic data hubs in electricity system. Retrieved 6th February 2020 from https://www.nordicenergy.org/wp-content/uploads/2017/12/Nordic-Data-Hubs-in-Electricity-System-1.pdf

Nordic Energy Regulators (2018). The Nordic energy regulators expect a move to a 15 minutes imbalance settlement period by 18 December 2020. Retrieved 5th February 2020 from http://www.nordicenergyregulators.org/2018/12/the-nordic-energy-regulators-expect-a-move-to-a-15-minutes-imbalance-settlement-period-by-18-december-2020/

Ocker, F., & Jaenisch, V. (2020). The way towards European electricity intraday auctions–Status quo and future developments. *Energy Policy*, 145, 111731.

Olsen, O. J., Johnsen, T. A., & Lewis, P. (2006). A mixed Nordic experience: implementing competitive retail electricity markets for household customers. *The Electricity Journal, 19*(9), 37-44

Orcutt, M. (2019). Once hailed as unhackable, blockchains are now getting hacked. Retrieved 6th February 2020 from https://www.technologyreview.com/s/612974/once-hailed-as-unhackable-blockchains-are-now-getting-hacked/

Orlov, A. (2017). *Blockchain in the electricity market: identification and analysis of business models* (Master's thesis).

Østli, P.O. (2019). Elhub is now operational. Retrieved 5th February 2020 from https://www.statnett.no/en/about-statnett/news-and-press-releases/news-archive-2019/elhub-is-now-operational/

Pahkala, T., Uimonen, H., & Väre, V. (2018). Flexible and customer-centred electricity system; Final report of the Smart Grid Working Group.

Peng, D., & Poudineh, R. (2019). Electricity market design under increasing renewable energy penetration: Misalignments observed in the European Union. *Utilities Policy, 61*, 100970.

Rahimi, F., & Ipakchi, A. (2010, January). Overview of demand response under the smart grid and market paradigms. In *2010 Innovative Smart Grid Technologies (ISGT)* (pp. 1-7). IEEE.

Raskin, M. (2016). The law and legality of smart contracts.

Repo, S., Gröhn, M., Saarinen, L., Kuosmanen, T., Aalto, J., & Soronen, S. (2020, September). The Definition of the Demand Response Interface for Next-Generation Smart Meters. In *2020 17th International Conference on the European Energy Market (EEM)* (pp. 1-6). IEEE.

Sabounchi, M., & Wei, J. (2017, November). Towards resilient networked microgrids: Blockchain-enabled peer-to-peer electricity trading mechanism. In *2017 IEEE Conference on Energy Internet and Energy System Integration (EI2)* (pp. 1-5). IEEE.

Samaniego, M., & Deters, R. (2016, December). Blockchain as a Service for IoT. In *2016 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical* *and Social Computing (CPSCom) and IEEE Smart Data (SmartData)* (pp. 433-436). IEEE.

Scherer, M. (2017). Performance and scalability of blockchain networks and smart contracts.

Schultze, U., & Avital, M. (2011). Designing interviews to generate rich data for information systems research. *Information and organization, 21*(1), 1-16.

Staff, E. (2016). Blockchains: The great chain of being sure about things. *The Economist, 18.*

Svenska Kraftnät (2019). Data hub. Retrieved 5th February 2020 from https://www.svk.se/en/stakeholder-portal/Electricity-market/data-hub/

Szabo, N. (1997). The idea of smart contracts. *Nick Szabo's Papers and Concise Tutorials, 6.*

TenneT (2020). Blockchain Technology. Retrieved 16th October 2020 from https://www.tennet.eu/our-key-tasks/innovations/blockchain-technology/

Tikka, V., Mashlakov, A., Kulmala, A., Repo, S., Aro, M., Keski-Koukkari, A., ... & Partanen, J. (2019). Integrated business platform of distributed energy resources–Case Finland. *Energy Procedia, 158*, 6637-6644.

Tómasson, E., & Söder, L. (2020). Coordinated optimal strategic demand reserve procurement in multi-area power systems. *Applied Energy, 270*, 114984.

Truby, J. (2018). Decarbonizing Bitcoin: Law and policy choices for reducing the energy consumption of Blockchain technologies and digital currencies. *Energy research & social science, 44*, 399-410.

Tuunanen, J. (2015). Modelling of changes in electricity end-use and their impacts on electricity distribution.

Underwood, S. (2016). Blockchain beyond bitcoin.

van der Veen, R. A., & Hakvoort, R. A. (2016). The electricity balancing market: Exploring the design challenge. *Utilities Policy, 43*, 186-194.

Valtioneuvosto (2019). Datahub Go-Live date to be postponed to 2022. Retrieved February 2020 from https://valtioneuvosto.fi/en/article/-/asset_publisher/1410877/datahubin-kayttoonottopaiva-siirtyy-vuoteen-2022

Valtioneuvosto. Carbon neutral Finland that protects biodiversity. Retrieved 4th February 2020 from https://valtioneuvosto.fi/en/rinne/government-programme/carbon-neutral-finland-that-protects-biodiversity

Wang, C., & Zhang, P. (2012). The evolution of social commerce: The people, management, technology, and information dimensions. *Communications of the association for information systems, 31*(1), 5.

Williams, C. (2007). Research methods. *Journal of Business & Economics Research (JBER), 5*(3).

Xu, X., Pautasso, C., Zhu, L., Gramoli, V., Ponomarev, A., Tran, A. B., & Chen, S. (2016, April). The blockchain as a software connector. In *2016 13th Working IEEE/IFIP Conference on Software Architecture (WICSA)* (pp. 182-191). IEEE.

Zhang, C., Wu, J., Zhou, Y., Cheng, M., & Long, C. (2018). Peer-to-Peer energy trading in a Microgrid. *Applied Energy, 220*, 1-12.

Zheng, J., Gao, D. W., & Lin, L. (2013, April). Smart meters in smart grid: An overview. In *2013 IEEE Green Technologies Conference (GreenTech)* (pp. 57-64). IEEE.

Zhou, K., Yang, S., & Shao, Z. (2016). Energy internet: the business perspective. *Applied Energy, 178*, 212-222.

APPENDIX 1 INTERVIEW FRAME

BACKGROUND INFORMATION

1. Please introduce yourself, where do you work, for how many years, and what is your job title?
2. How would you assess your knowledge concerning the Finnish energy market?

ENERGY SECTOR

1. How would you describe the current state of the Finnish, Nordic, and European Energy sector?
2. What emerging trends do you observe?
3. Who are the most important stakeholders in the energy sector?
4. Do you observe certain tension points or problems in the energy industry?
5. How does a typical energy supply contract look from an end user perspective?
6. How does a typical energy supply contract look from a network providers and retailers' perspective?
7. Scenario: Consumer has a new apartment and wants to have electricity? What are the steps they need to do to get electricity?
8. What is happening after the consumer has done their part? What is happening behind the scenes after that?
9. Can you name all actors that are involved after the consumer has ordered the electricity?

BLOCKCHAIN AND SMART CONTRACT SYSTEMS IN THE ENERGY SECTOR

10. Are you aware of blockchain and/or smart contracts? How would you describe them?
11. What is your view on blockchain and/or smart contracts in the energy sector? In what ways do you think smart contracts or blockchain could be used in the energy sector?
12. Do you think smart contracts or blockchain could be used in the consumer or prosumer context?
13. In which part of the normal contracting process could smart contracts be applied? Is this a B2C or B2B solution or both?
14. Could blockchain technology and/or smart contracts be utilized in whole markets of electricity?
15. What are the technological and business-related opportunities of smart contracts in the energy business?
16. What are the technological and business-related risks of smart contracts in the energy business?

17. Would you say these smart contract solutions should be done by external technology providers or by the Finnish energy providers themselves?
18. In your view, what needs to be done before blockchain technology and/or smart contracts are ready for the energy business?

ADDITIONAL COMMENTS

19. Would you like to add something that hasn't been discussed yet?