# Blockchain in the Electricity Market: Identification and Analysis of Business Models

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Abstract

This paper aims to identify the business models used by blockchain-based initiatives and projects in the electricity market and identify how they affect it. This research examines the market trends within the electricity market as well as general socioeconomic and technological developments.

This paper is based on a conceptual analysis of case studies that utilise blockchain technology in the electricity market and an empirical evaluation of considerations that have to be made when implementing a peer-to-peer energy-trading platform. For the conceptual analysis, a four-dimensional business model framework has been defined. To specify the dimensions of the business model, categories and characteristics have been identified that have been determined to be characteristic to the 22 analysed case studies. Seven business model archetypes were subsequently derived from the initial four-dimensional review of the case studies.

This paper adds value to both research and practice in three ways. First, it facilitates discussions about blockchains in the electricity market and their practical use. Second, it sheds light on the implications of their use on the electricity market and its participants. Third, it highlights what factors need to be considered when implementing a blockchain-based P2P energy-trading platform.

While the first energy blockchain project was introduced in 2015, at the time this paper was submitted it was the first publication that analysed blockchain-based business models in the electricity market. In writing this paper, the author has assumed that readers have only little knowledge of blockchain technologies and the opportunities for their application in the energy market.

**Key words**: energy blockchain, peer-to-peer energy trading, business models, electricity market, blockchain

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# List of abbreviations

API  Application programming interface

CAISO  California Independent System Operator

COP  Conference of the Parties

DER  distributed energy resources, distributed energy resources

DSO  Distribution System Operator

EMTS  Energy management trading system

EV  Electric vehicle

ICT  Information and communication technologies

IEA  International Energy Agency

IoT  Internet of Things

IPCC  Intergovernmental Panel on Climate Change

ITO  Initial Token Offering

M2M  Machine-to-machine

NVE  Norwegian water resources and energy directorate

OTC  Over-the-counter

P2P  Peer-to-peer

PwC  PricewaterhouseCoopers

RES  Renewable energy sources

TWh  Terrawatt hours

# 1. Introduction

## 1.1 Relevance of the research topic and problem statement

The early stages of electrification at the end of the 19th century set the agenda for the electricity system of the 20th century. As one electrical grid is sufficient to connect the power generating utilities with consumers, regional utility companies formed natural monopolies and were vertically integrated into the electricity supply chain. Because of its monopolistic structure, the electricity sector was strongly regulated. Thanks to steady and reliable revenues, this allowed the utility companies to make long-term investments to further expand the grid and to increase supply with new power plants.

Since the 1990s, the sector has been restructured in Europe and North America. Utilities were gradually unbundled so that the grid is now openly accessible. Competition increased following the introduction of wholesale and retail markets. As a consequence, the market design of the electricity sector became more complex. Recently, climate change policies have heavily incentivised the deployment of renewable energy sources (RES). This development has increased complexity further as the intermittent nature of most RES causes fluctuations which are hard to control. In addition, the expansion of RES strains established utilities and hampers grid infrastructure investment. To mitigate the fluctuations, several strategies are already in use. For instance, controllability can be improved by curtailing RES units or making use of flexible sources. From a technical standpoint, better measurements and predictions of power in-feed from RES can improve the integration of renewables.

In recent years, information and communication technologies (ICT) have affected multiple industries by changing the nature of living and doing business. As the electricity grid is based largely on technology from the first half of the 20th century, ICT could enable the upgrade of old grid infrastructure to accommodate the changing nature of the power system due to RES and to foster opportunities for grid control and electricity trading. In addition, newer technologies fuel expectations for the so-called energy internet – a highly interconnected and distributed energy network which becomes part of the Internet of Things (IoT). Prospects include higher efficiencies, security of supply, and the further break-up of the historically monopolistic ownership structure.

A potentially major force for disruption to the way of doing business appeared in 2009. A person or group unknown to the public, called Satoshi Nakamoto, implemented a peer-to-peer (P2P) electronic cash system which runs on a publicly distributed ledger. The technology is commonly referred to as the blockchain and was introduced together with the cryptocurrency Bitcoin. In essence, blockchain technology allows P2P transactions within a network without relying on an intermediary or a central institution. In the financial services industry, banks and insurers are currently investing in blockchain solutions in order to reduce friction and costs (HBR, 2017). Likewise, the blockchain attracts increasing interest within the energy sector. The first widely known project was the Brooklyn Microgrid, launched in a neighbourhood in Brooklyn, New York. The project successfully implemented a P2P electricity trading platform based on the blockchain in a microgrid setting. Around the world, several blockchain have been introduced by start-ups and utility companies such as Vattenfall in the Netherlands, Innogy in Germany, Wien Energie in Austria and Power Ledger in Australia. Pilot projects and potential applications encompass the complete electricity value chain: P2P and wholesale trading, electric vehicle (EV) charging and sharing, metering and billing, and guarantees of origin (Indigo Advisory Group, n.d.; PwC, 2016). Even though the blockchain has already been successfully implemented on a microgrid level, many uncertainties remain at the large-scale implementation level regarding how the technology fits into the current electricity market design. The unanswered questions include the required characteristics of the blockchain, its consequences for existing and new market actors, its impact on electricity market design as well as economic and regulatory issues. Consequently, the blockchain may – hand in hand with broad technological changes and the liberalisation of the electricity market – further change the business landscape. As these trends allow for new business models to thrive, small enterprises will continue to enter the electricity value chain to offer services and solutions along the smart-grid value chain.

## 1.2 Research question, aim and scope of the thesis

Blockchain-based applications within the electricity market are not only new to the energy business but also a young field within academic research. Researchers so far have analysed how blockchain technology can support the energy management of the distribution grid and within residential microgrids while integrating distributed RES (Danzi, Angjelichinoski, Stefanović, & Popovski, 2017; Horta, Kofman, & Menga, 2016). Furthermore, Mihaylov and Van Moffaert have introduced a digital currency that allows prosumers on the smart grid to trade their produced renewable energy (Mihaylov, Razo-Zapata, Rădulescu, & Nowé, 2016). Tai, Sun and Guo have looked more closely at blockchain-based electricity transactions and congestion management (Tai, Sun, & Guo, 2016). While the academic research mentioned analyses how blockchain technology can be used to solve some of the open questions and issues concerning the electricity market, it does not address business cases and opportunities. Research covers business models involving the smart grid or explores business models that encourage the flexibility of distributed energy resources (DER). Hence, there is a research gap regarding business models based on the blockchain within the electricity market.

The objective of the thesis is to identify blockchain-based business models within the electricity market and to analyse the applicable business models' value proposition for prosumers and consumers. The thesis investigates how the blockchain can be implemented to facilitate a climate-friendly and distributed energy system. Against this backdrop, the research described here particularly focuses on the consequences to the energy market, and its market participants. Hence, the following questions are raised and addressed in this thesis:

| | |
|---|---|
| Clarifying questions | - What are the leading trends and requirements regarding a distributed and decentralised electricity system?<br>- What are distributed ledger technologies and the blockchain? |
| Research questions | - What are the existing blockchain-based business models within the electricity market?<br>- How do these business models affect the electricity market and the value chain?<br>- What needs to be considered when implementing a blockchain-based P2P energy-trading platform? |

*Table 1: Clarifying and research questions*

## 1.3 Structure of the thesis

The core of the thesis consists of six chapters. Following the introduction, Chapters 2 and 3 establish the building blocks of the thesis and address the clarifying questions listed in section 1.2. Chapter 2 introduces the current electricity system and the trends that led to its current structural challenges. Chapter 3 explores general technological and economic developments, in particular the sharing economy and blockchain technology. Blockchain technology is the focus of section 3.2 in order to shed light on the meaning and functioning of the the technology. Next, Chapter 4 explains the research methodology, laying out the analytical framework for the subsequent research. Chapters 5 and 6 aim to answer the research questions mentioned in section 1.2. The emerging blockchain-based business models are analysed (Ch. 5 and Appendix C-E). After this, considerations for a P2P energy-trading platform are made. Electricity consumption and production data from a smart-grid pilot in Hvaler, Norway, serves as the basis to evaluate the business case for blockchain applications in this area (Ch. 6). Chapter 9 completes the main part of the thesis and describes and discusses the main findings and limitations.

## 1.4 Literature review

The blockchain within the energy or electricity market context is increasingly gaining attention in academic literature and in practice. This literature review is based on the following databases and search engines: EBSCO Discovery Services by the HEC Paris library, Oria by the Norwegian School of Economics, Google Scholar and Google. The research was conducted to gain an overview of the developments of the blockchain within the energy market and the blockchain's future role. The research therefore centred on the following keywords: 'energy/electricity blockchain' and 'blockchain in the energy/electricity market/sector'.

| Author | Type | Research area | Method |
|---|---|---|---|
| Sikorski, Haughton, & Kraft (2016) | Journal article | Electricity trading; machine-to-machine (M2M) transactions | Proof-of-concept |
| Tai et al. (2016) | Journal article | Electricity trading; congestion management; smart contract | Case scenario |
| Mihaylov, Jurado, & Avellana (2014) | Conference proceedings | Electricity trading; digital currency | Theoretical concept |
| Danzi et al. (2017) | Journal article | Electricity trading; proportional-fairness-control; smart contract | Simulation |

| | | | |
|---|---|---|---|
| Merz (2016) | Book chapter | Electricity trading; blockchain properties | Conceptualisation |
| Bertsch, Elberg, Helgeson, Knaut, & Tode (2017) | Report | Economic feasibility; P2P electricity trading | Qualitative study |
| Degode (2016) | Seminar paper | Energy trading; smart contracts; microgrids | Qualitative evaluation and discussion |
| PwC (2016) | Report | Energy trading; blockchain properties; use cases | Qualitative evaluation and discussion |
| CGI Group (2017) | Report | Energy trading; blockchain properties; use cases | Qualitative evaluation and discussion |
| Deloitte (2016) | Report | Energy trading; smart contracts | Qualitative evaluation and discussion |
| Cohn, West, & Parker (2017) | Journal article | Smart contracts; energy usage feedback; micropayments; microgrids | Implementation analysis under a legal framework |
| Burger, Kuhlmann, Richard, & Weinmann (2016) | Report | Use cases; smart contracts; P2P; regulation | Survey; qualitative evaluation and discussion |
| Federico (2016) | Presentation | P2P; smart contracts; energy trading | Qualitative evaluation |
| Hagström & Dahlquist (2017) | Thesis | Scalability; payment system; electrified roads | Interviews; qualitative evaluation and discussion |
| Horta et al. (2016) | Report | Demand-side flexibility; Virtual Distribution Grids; Distribution System Operator (DSO); energy management | Qualitative evaluation and discussion |
| Johnson, Isam, Gogerty, & Zitoli (2015) | Report | Digital currency; application programming interface (API); solar energy | Laboratory testing |
| Konashevych (2016) | Journal article | Microgrids; P2P; blockchain properties | Qualitative analysis and discussion |

| | | | |
|---|---|---|---|
| Lilic & Lundfall (2016) | Presentation | Prosumer; API; blockchain architecture | Conceptualisation |
| Mattila et al. (2016) | Working paper | M2M transactions; blockchain properties | Qualitative analysis, conceptualisation and discussion |
| Mengelkamp, Gärttner et al. (2017) | Journal article | Microgrids; P2P; blockchain properties | Qualitative analysis, conceptualisation and discussion |
| Mengelkamp, Notheisen, Beer, Dauer, & Weinhardt (2017) | Journal article | Market design | Simulation of blockchain-based local energy market |
| Imbault, Swiatek, De Beaufort, & Plana (2017) | Conference proceedings | Microgrid; blockchain architecture; market design; green certificates | Conceptualisation; demonstration |

*Table 2: Literature overview of blockchain in the electricity market*

First, the summary of the literature review reveals that blockchain within the energy market is predominantly associated with energy trading, P2P and smart contracts, followed by discussions of blockchain properties and use cases. Second, literature on this topic is dominated by publications from management consultancies (CGI Group, 2017; Deloitte, 2016; PwC, 2016) and other non-academic institutions (i.e. white papers by start-ups). PricewaterhouseCoopers (PwC) has issued a concise publication on the blockchain within the energy sector. The company mapped out blockchain applications and use cases along the electricity value chain and regularly publish updated publications on developments in this area. Third, few journal articles actually address the technical aspects of blockchain applications in the context of electricity trading or energy management. In contrast, non-academic publications address the topic in broader terms and less specifically than academic research. Given the early phase of the blockchain in the energy market, academic research is therefore only slowly picking up on this research topic. To conclude, current academic research and publications centre around energy-trading platforms based on the blockchain, general blockchain properties, smart contracts and digital currencies. Some publications address the blockchain as a means to address prevailing challenges within the energy market. The analysis, however, remains on a technical level and does not extend to how the blockchain should actually be implemented from a business point of view. It remains undecided which specific business cases and opportunities address each type of challenge.

The research covers business models regarding the smart grid or explores business models that encourage the flexibility of distributed energy resources (DER) (Hall & Roelich, 2016; Richter, 2012; Rodriguez-Molina, Martinez-Nunez, Martinez, & Perez-Aguiar, 2014; Shen, Jiang, & Li, 2015). There is a research gap regarding business models based on the blockchain within the electricity market. This research gap between technical, academic research and use-case-oriented company publications is addressed by this thesis.

# 2. Market trends introducing structural challenges to the electricity system

This chapter lays out structural challenges to the electricity system. First, the main components of the electricity system are introduced and explained. Based on these, four trends within the electricity market, namely climate change, decentralization, digitalization, and electrification are explained to show how they influence the structure of the electricity system. Together with the developments outside the electricity system that are subsequently introduced in Chapter 3, the following section therefore lays the foundation for the analysis of blockchain-based electricity markets. It serves as a basis to enable the analysis of how the developments external to the electricity market can be utilized to address the challenges and trends within the electricity market.

## 2.1 Theoretical foundation: the electricity system

The electricity system consists of two components: the electricity grid and an organised electricity market. The electricity grid pertains to the flow of electricity. It ensures the power transportation and is differentiated into a transmission and distribution grid for long and short distances, respectively. The electricity market comprises the organizational structure of the market, its participants, and their approach of interaction.

### 2.1.1 Electricity grid

According to Wangensteen (2012) the electricity grid is responsible for the transmission and distribution of power from the generators to the consumers. Power plants generate electricity, which is then converted from a low voltage to high voltage in order to be efficiently transported. The transport is effected by means of high-voltage transmission lines that cross long distances. After this step, high-voltage electricity is converted back to low voltage in order to distribute the electricity at a regional level. Distribution lines carry the low-voltage electricity to consumers. Conversion between the voltage levels is done by transformers at substations. High-voltage electricity is more efficient and less expensive for long-distance transmission, while a low voltage is safer and suited for industrial and residential usage and applications.

### 2.1.2 Electricity market

The focus of this section is on introducing the development of the market structure of the electricity market, explaining the responsibilities of the market players (divided into supply and demand), and outlining how energy trading among market players is organized. restructured electricity markets as these can be found in Europe.

In a traditional market structure, power was supplied by a vertically integrated system operator (SO) responsible for the supply side. This meant that along the electricity-supply value chain, transmission and distribution formed natural monopolies. As for the power supply, one transmission and distribution grid is sufficient. Hence, a single operating company profits from economies of scale, contrary to if there were parallel grids operated by several companies (Wangensteen, 2012).

In order to increase efficiency and public welfare, restructuring of the power market started at the beginning of the 1990s in Europe. While public ownership was still predominant, integrated operators were split up vertically. Following this, power generation became fully competitive, while the transmission system (TSO) and distribution system operators (DSO) were operated under strict regulations as they both share characteristics of natural monopolies. Power-generating companies are typically referred to as independent power producers and are today only responsible for power production. In addition, the liberalisation allowed new power producers to enter the market and therefore increased competition. (Wangensteen, 2012)

The *TSOs* within the restructured electricity market own and operate the main grids. They are responsible for securing a constant supply by balancing power, maintaining sufficient capacity margins within the generating system and the grid as well as for controlling the frequency and voltage. Being in charge of operating the grids also means that the TSO is responsible for extending the network if necessary. It therefore opens the grid to third parties and connects customers to it. Consequently, the TSO is remunerated by charging a tariff whenever electricity is sold to the customer. In Norway and Germany, TSOs additionally have the role of a balance responsible party, meaning they are responsible for imbalance settlements. (Wangensteen, 2012)

*Regulatory authorities* have oversight over the monopolistic activities of the SO and the grid companies. They aim for market efficiency by ensuring third-party access and controlling tariffs and revenues for the grid companies. In Norway, the regulator in charge of the electricity sector is the Norwegian Water Resources and Energy Directorate (NVE). In Germany, the counterpart is the Federal Network Agency (German: Bundesnetzagentur, BNetzA).

As the power system is physically interconnected, a *power exchange* simplifies the process of finding a market equilibrium. The power exchange manages bids for sales and purchases of electricity so that prices and quantity get settled. In the Nordic countries, the regional power exchange is Nord Pool; in Germany, it is the European Energy Exchange (EPEX).

Lastly, consumers currently follow their own consumption patterns and are not under direct control of the suppliers. To a great degree, consumers can freely choose their suppliers. To simplify tracking power usage, metering equipment is installed at a consumer's premises and it records hourly consumption. Further technological development has opened opportunities for two-way communication and direct control through affecting electricity pricing, which may incentivise the consumer to change his or her consumption pattern. (Wangensteen, 2012)

Electricity demand or consumption is price-inelastic in the short term due to the absence of substitutes for electricity. The electricity demand can be depicted as a load-duration curve. It is influenced by the consumers' individual demand that fluctuates over time. Residential, commercial and industrial consumers have different load patterns, which in turn depend to different degrees on external factors. Generally speaking, while households peak in the morning and late afternoon/evening, offices consume the most energy during the day. Both households and offices are temperature-dependent, which is reflected in the electricity demand for heating and air-conditioning. At a grid level, the individual load curves are aggregated. The electricity demand that needs to be covered is commonly referred to as peak-, mid- and base-load according to the different load levels. (Wangensteen, 2012)

### *Electricity market design and trading*

The prevailing condition for the electricity market design, after its restructuring, is full market access for all participants on both the supply and demand side. Full market access addresses not only legal access but moreover access to all information regarding prices and supply conditions.

Electricity transport from generators to consumers is facilitated by a pool or spot exchange. Within this market, the output from all generators is aggregated and scheduled at five-minute intervals to meet the demand. There are two markets: wholesale and retail. The wholesale markets facilitate the buying and selling of electricity between the generators and the DSOs. Within the retail market, electricity is sold to the consumers by the DSOs. Usually, only one physical spot exchange exists per region because of higher aggregated liquidity, which can decrease uncertainty and volatility on the market. Furthermore, the spot exchange generates one spot price as a reference for financial trade.

There are two major procedures for to attain the settlement price in the exchange: periodic clearing and continuous auction. In the periodic clearing process all the information through one or more repeated bids is collected. As a result, all participants receive the clearing price, which equals the short-term marginal cost. Furthermore, periodic clearing can be operated using either centralised or decentralised scheduling. In centralised scheduling systems, all the information on cost and the restrictions of the generating units is taken into account. In contrast, the decentralised scheduling mechanism determines the clearing price and traded quantity by the intersection of the sales and purchases curves, which resemble the aggregated bids. The companies therefore base their bids on price forecasts, as the clearing price is set for one hour at a time. Continuous auctions involve bidders getting paid for the price which they were offering on the market, hence the so-called pay-as-bid price. A prerequisite of the continuous clearing process is decentralised scheduling, as the physical trading transactions are bilateral in nature. Adjustments are made using the balancing market.

In addition to the spot market, which closes hours before real time, there is a balancing market. On this market, reserves are made available in case some constraints are violated. This is usually the task of the SO, which has two options: acquiring reserves and remunerating the market participants who made them available, or defining the requirements and distributing the balancing obligation to other companies. Both solutions, depending on the generating units, involve costs for keeping the reserves available in addition to making actual use of it.

Apart from physical trading markets, the financial market excludes physical delivery of electricity and focuses on financial transactions only. The reference price for financial trades is typically the spot price.

## 2.2 Trends

The trends which shape the electricity market span a wide range from politics to technological advancements and from economic considerations to scientific evidence for climate change caused by human activity. Naturally, some driving forces are interlinked or interdependent on one another. The following sections outline the main drivers of the energy transition and the influencing factors causing major challenges to the electricity system.

### 2.2.1 Climate change

Under the leadership of the Intergovernmental Panel on Climate Change (IPCC), independent scientists compiled evidence for human-made global warming, commonly referred to as climate change, and its impact on the planet. In 1990, the IPCC issued its first assessment report summarising different global-warming scenarios. Greenhouse-gas emissions from human activities (transportation, heating, agriculture, manufacturing, etc.) are causing global warming. Global warming has potential climate-related impacts such as droughts, extreme weather, natural catastrophes, sea-level rise and the extinction of species. The predominant consensus is that burning fossil fuels is the main cause of GHG emissions, in addition to other activities such as agriculture. Therefore, fossil-fuel-driven activities need to be reduced, or fossil fuels have to be replaced by different forms of energy. As fossil fuels were the main fuel source for over a century, whole industries and businesses now rely on a supply of them. Switching to low-carbon energy carriers requires investments and technological developments. Even when climate change first become widely understood, companies were hesitant to implement adequate measures voluntarily. As a result, climate change became a high-level political issue.

In 1997, the Kyoto Conference of the Parties (COP) definitivelylaid out the foundation for a broader consideration of climate change with regard to its implications on countries, the economy and communities. In Kyoto, countries agreed to reduce GHG emissions on a country-by-country basis, differentiating the levels mainly between industrialised and developing countries. Later, at the COP 21 in Paris, the countries agreed for the first time on a framework in which all countries contribute to reduce GHG emissions, while developing and vulnerable countries get financial and capacity-building support. The common goal of limiting the rise in temperature to two degrees Celsius or less should be reached through nationally determined contributions. Consequently, countries are increasingly developing climate policies and implementing regulations to which the companies have to adhere on a national level.

Climate change and the resulting policies and regulations affect both energy supply and demand. Firstly, climate change has an impact on future heating and cooling demands. As hot regions become increasingly hot, the demand for electricity increases as a consequence of using cooling devices. In contrast, in cold regions the electricity demand might decrease in the spring if the warm season started earlier (Cian, Lanzi, & Roson, 2007; U.S. Environmental Protection Agency, 2017). With the transparency initiative CDP[1], which encourages the disclosure of carbon emissions by companies, more and more companies are setting emission reduction targets (CDP, 2017). Companies are therefore striving for higher energy efficiency, which reduces the overall energy demand, or are preferentially purchasing renewable electricity, which consequently increases the demand for renewable energy. In other words, not only are countries taking action on climate change, but companies are also committing to sourcing energy as sustainable as possible. For instance, the global initiative RE100[2] is uniting companies which commit to sourcing 100% renewable electricity (RE100, 2017). Secondly, climate change also impacts the energy supply. As ambient temperatures rise, thermal power plants become less efficient at thermal conversion. Looking at infrastructure, oil and gas pipelines in coastal areas as well as power lines could be damaged during extreme weather events, which occur more often due to global warming (WEC, CJBS, & CISL, 2014).

### 2.2.2 Decentralisation

Decentralisation within the energy sector means that energy is produced close to where it is consumed. Decentralisation is therefore enabled by technologies falling within the field of distributed generation. Distributed energy sources include combined heat and power plants as well as RES. With the need for low-carbon energy carriers and the liberalisation of the energy sector, RES, notably solar photovoltaic and wind, have been growing tremendously. In 2016, new solar PV capacity grew globally by 50%, adding a total of nearly 75 gigawatts (IEA, 2017). In comparison, gas fuelled capacity was grew by around 27 gigawatts globally

[1] Formerly called the Carbon Disclosure Project, CDP is running a global disclosure system regarding environmental impacts. Over 5,600 companies self-report environmental data using the platform.

[2] Among the committed companies are IKEA, Apple, BMW Group, Kellogg, JPMorgan Chase & Co. and others.

(ibid.). The growth is attributable especially to governmental subsidies and decreasing technology costs.

Decentralisation reduces transmission losses, thanks to more distributed energy generation, and lowers carbon emissions due to a higher share of RES (given that energy demand remains constant). In addition, the larger number of energy suppliers increases the overall security of supply compared to a state with fewer, central power plants.

In some countries, decentralisation has seen an upswing in a novel form of energy generation and distribution via regulations that allow P2P electricity markets. In Switzerland, the Energy Strategy 2050 passed in May 2017. While it determines goals and measures for energy efficiency, nuclear phase-out and renewable energies, it also promotes prosumerism and communal energy trading (UVEK, 2017).

### 2.2.3 Electrification

Electrification describes the increasing share of electricity in satisfying total energy demand, meaning that fossil fuels are being replaced with electricity. According to the International Energy Agency (IEA), electricity accounts for the largest relative increase of all energy sources within end-use sectors. The IEA estimates that the share of electricity of the final energy demand will rise from 18% in 2017 to 26% by 2060[3] (International Energy Agency, 2017b). This growth is due to the ambitions to reduce greenhouse-gas emissions in accordance with communal efforts to lessen air pollution and international efforts to combat climate change.

Electrification is taking place within two sectors especially: heating and transport. For instance, the Danish government announced in its plan ‘Our Energy Future’ the goal to have all heating generated by using 100% RES by 2035 (Danish Energy Agency, 2011). In the field of heating, heat pumps for the heating and cooling of buildings can replace the predominant use of natural gas for electricity. Within the sector of transportation, on-road electrification dominates. On the road, electric or hybrid vehicles are a growing market in the automobiles industry. In 2016, the estimated share of hybrid and battery-electric vehicles was 60% and grew to an estimated stock of two million EVs worldwide. According to the

[3] Estimate by the IEA for the Reference Technology Scenario, which takes into account the current state of energy and climate-change commitments by countries (International Energy Agency, 2017b).

IEA's conservative Reference Technology Scenario, the stock will grow to 60 million by 2030. In contrast, the scenario in accordance with the Paris Declaration projects almost 120 million EVs by 2030 (International Energy Agency, 2017c).

Yet, in the process of electrification for the purpose of decarbonising the two sectors, the primary energy source for the electricity has be taken into account in order to have a positive impact towards reaching climate-change goals. Consequently, the Danish government also set a target to have not only heating but all electricity generated by RES. The importance of this issue can be illustrated by comparing the electricity mix and the corresponding GHG emissions of Germany and Norway. In 2016, half of Germany's electricity generation came from fossil fuels (51%); 16% came from nuclear energy and 33% was attributable to RES (Fraunhofer-Institut für Solare Energiesysteme, 2016). The CO2 emissions resulting from this electricity mix amounted to 534 g/kWh (Umweltbundesamt, 2017). In contrast, the Norwegian electricity mix is much less carbon-intensive, thanks to a 96% share of hydro-power and another 2% share of wind power in 2015 (Statistics Norway, 2016). As a result, the CO2 emissions from electricity production were estimated to be 17 g/kWh in 2015 (NVE, 2016). In sum, for a transition towards a low-carbon economy, it is not sufficient to transform the sectors relying on fossil fuels but the sources for electricity generation must be revamped as well.

### 2.2.4 Digitalisation

According to the World Economic Forum (2017) digitalisation is transforming the way energy business is done. Within the energy sector, digitalisation is impacting the complete value chain. Overall, digitalisation within the electricity sector builds upon implemented network technologies, which are oftentimes summarised under the umbrella of smart metering, smart grid, and smart home. On the energy-supply end, digitalisation allows to improve operational productivity, the efficiency of assets as well as of the transmission and distribution network by remote monitoring, diagnostics, control, and automation (McKinsey, 2016). Further implications of the digital transformation arise on the demand side. First, at the intersection of consumers and DSOs, demand response can be optimised. Second, interactions with customers can be enhanced with connected homes and omni-channel solutions from the utility companies or other service providers (Accenture, 2014). Moreover, over the course of the digital transformation of the electricity sector new roles arise, and therefore new players enter the market with digital solutions superior to those of established utility companies.

## 2.3 Challenges

Taking the described trends into account, several challenges arise within the electricity market. Especially RES place economic and technological pressure on the current system. First, solar photovoltaic and wind power are more dependent on the weather, which means that generation from these sources is intermittent and unpredictable compared to conventional, centralised power generation. Hence, one of the major challenges is to match energy consumption and production adequately and continuously. This sets new requirements for electricity market design. Second, due to the lower marginal costs of these energy resources, average electricity prices are declining. Both drawbacks are discussed below.

### *Technological challenges*

The trend of climate change and the resulting increasing interest in cleaner, less carbon-intensive energy sources drives the adoption of RES. Furthermore, the trend of decentralisation facilitates the deployment of small-scale facilities that generate power from renewable sources, for example PV facilities for private households. A major consequence of these two trends and the increasing deployment of renewable energies is that the load curve shifts. As PV produces energy during the day and feeds in electricity into the grid, the load during the PV generation hours shrinks. Meanwhile, the peak load in the early to late evening remains the same. The most prominent load pattern is the so-called Californian ‘duck chart’, oftentimes referred to as duck curve. In 2013, the California Independent System Operator (CAISO) predicted that the increase in PV generation will lead to a substantial drop in mid-day net load. It estimated that the effect would be especially strong in the spring, when the temperatures do not require cooling and the days are still quite sunny. Figure 2 demonstrates the net load curve during a spring day in California. As CAISO notes, “the net load is calculated by taking the forecasted load and subtracting the forecasted electricity production from variable generation resources, wind and solar” (CAISO, 2016). From 2014 onwards, the lowest point of the net load is around 2pm. At this point, the solar PV generation is at its highest. The net load is predicted to drop significantly during midday because of increased solar PV penetration and generation over the coming years. The net load curves progressively form a duck askew over the years, hence the name.

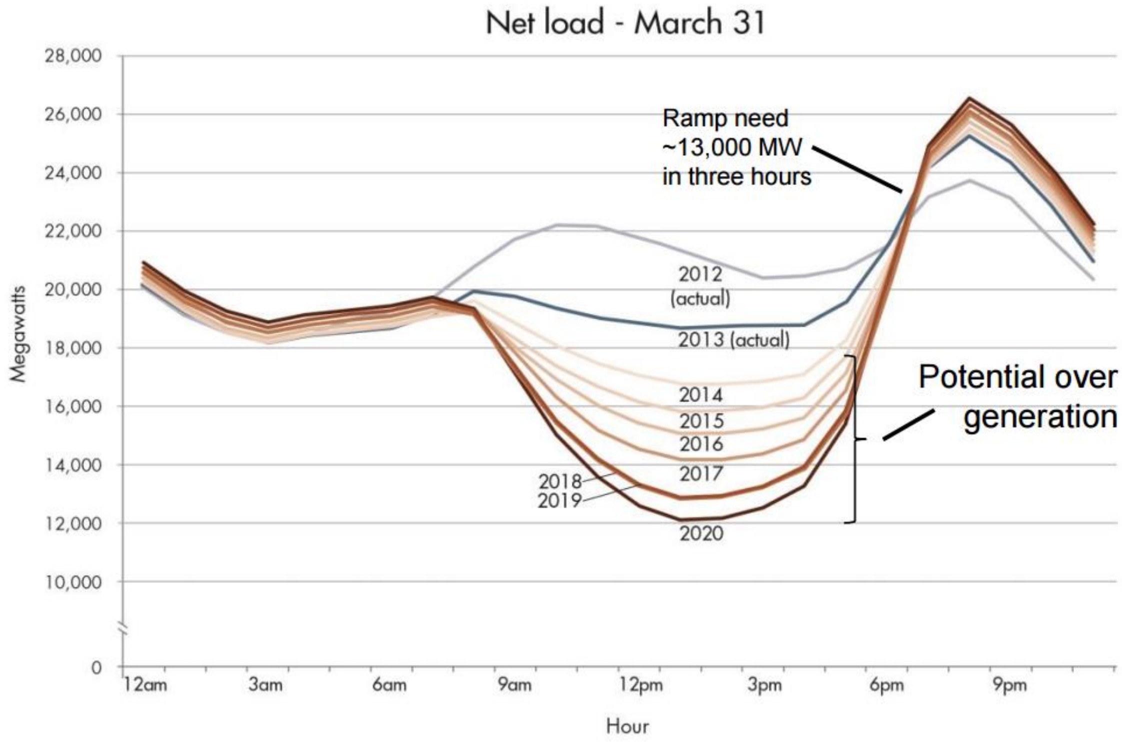



*Figure 1: Net load curve for the study day March 31, years 2012 through 2020 (By courtesy of CAISO in Burnett, 2016)*

The consequences for the power system are manifold. First, supply could exceed real-time electricity demand. The potential of over-generation is shown in Figure 2. Over-generation needs intervention from the system operator as it could otherwise damage the infrastructure. This intervention is done through the curtailment of the scheduled generation capacity. However, in the case of extreme over-generation, technological and economic limits restrict the curtailing solution approach. Due to the over-generation, the net load interferes with the base load, which is provided by energy generators that can barely be shut down on short notice. The second problem caused by over-generation is linked to the restricted adjustment potential of most of the production capacity: after the sunny PV generation hours during peak demand, the system operator needs to meet high ramping requirements in a few hours (Denholm, O'Connell, Brinkman, & Jorgenson, 2015).

### *Economic challenges*

Driven by decentralisation and increasing action to combat climate change, the higher grid penetration of PV and wind power leads to lower prices because RES operate at zero marginal costs once they are installed. Hence, RES are the first generation units to be utilised. This is also depicted in the form of the so-called merit order curve, also called the dispatch curve. Merit order refers to the order in which electricity generation sources are dispatched as demand rises, from the cheapest source to the most expensive at peak demand. On the one hand, the system is favourable to consumers. However, in the case of Germany, wholesale electricity prices are dropping while consumer prices rise due to an integrated subsidy mechanism for RES. On the other hand, the zero marginal costs are an economic pitfall for utility companies and investors. A high RES penetration and generation output during peak hours may even cause negative wholesale prices (De Vos, 2015).

# 3. Socio-economic and technological developments

After the trends within the electricity market and their impact on the resulting challenges have been discussed, the following chapter introduces technological and socio-economic developments that develop outside the electricity market: the sharing economy and the blockchain technology. This serves as a basis to analyse how a business model can utilize the blockchain and build upon existing trends to influence and address the challenges of the electricity market.

## 3.1 Sharing economy

The sharing economy is a highly ambiguous term for a socio-economic concept which broadly describes organised resource sharing by individuals using a platform; or, as Greenhouse (2016) describes it:

> It’s a hip, fast-growing sector of the economy, filled with headline-grabbing companies: Uber, Lyft, Airbnb, Task Rabbit. But there’s a gnawing problem: People aren’t sure what to call it. Many critics dislike the term most commonly used, the “sharing economy,” because there often isn’t much actual sharing going on. Others prefer to call it the on-demand economy, peer-to-peer economy, crowd-based economy, gig economy or collaborative economy. (Greenhouse, 2016, ¶ 1)

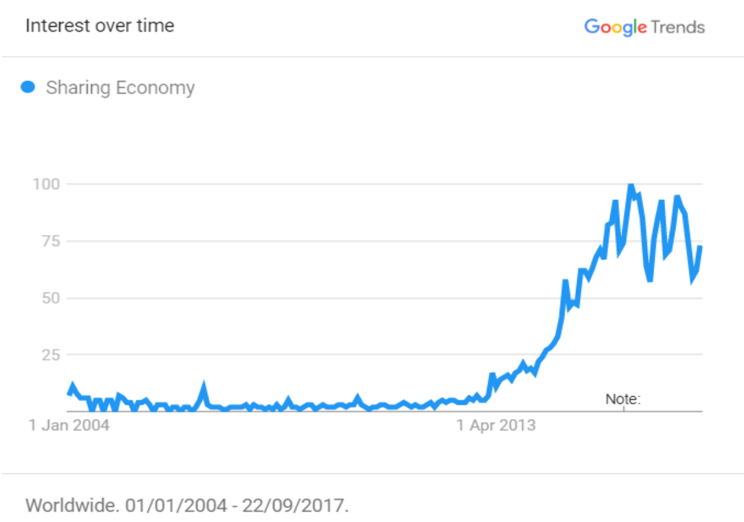
Greenhouse (2016) describes three relevant characteristics of the concept of sharing economy. First, it is described as a distinct part of the economy, yet a variety of companies are said to be part of it. The companies Uber and Blablacar are two prime example to exemplify how two ‘sharing-economy’ companies with a similar value offering for the customer (getting from one place ot another) use very different business and operating models. With a revenue of over US $6.5 billion in 2016 (Reuters, 2017), Uber is often cited as the most successful company in the mobility sector of the sharing economy. While Uber provides a smartphone application through which passengers can order a ride, the company does not provide cars; instead, the drivers are required to use or rent their own cars. The drivers are not permanent workers for Uber but rather self-employed contractors, and they therefore get paid for every ride. Blablacar is platform that connects drivers, who would want to drive from one place to another anyways, with potential co-riders (Botsman &

Rogers, 2010). Hence, the drivers are not offering their services as a direct answer to a co-riders demand: they can only offer to share their ride and then get contacted by interested co-riders. The co-riders pay the drivers a fee for petrol and for the running costs of the car. In summary, although both companies are considered to be part of the sharing economy, they follow very different business and operating models. With Uber, passengers order and pay for the ride as if it were a traditional taxi; only the way the service is organised has changed (LaPlante in Greenhouse, 2016, ¶ 3-4). With Blablacar, co-riders actually share their ride with drivers, as they actually also want to go in the same direction or to the same destination.

Second, there is broad disagreement regarding the term ‘sharing economy’ which describes the underlying platform market(s). The main reason for this is that the term sharing economy is used for a heterogeneous group of platforms, as described above,. The business and operating models differ significantly and so do their impacts on their user base and the broader society, giving rise to the discussion what sharing economy exactly entails. Researches increasingly question the appropriateness of the term sharing if consumers pay for a service or product (Greenhouse, 2016) and advocate for a different terminology, for example the term crowd-based capitalism as “consumers obtain services by connecting with a crowd of suppliers via a platform” (¶ 5).

Third, the sharing economy is a rapidly growing market and has only become generally known as such over the last few years. As an example, Figure 3 shows the search interest in the term ‘sharing economy’ with the search engine google.com since 2004. The graph line represents search interest relative to the highest point for the given period (01/01/2014–22/09/2017). The value of 100 represents the highest popularity for the term on a given day. At 50, the term was only half as popular. The figure shows that the term was highly popular in the years 2013 to 2017, as opposed to the previous ten years.

*Table 3:Interest over time in Sharing Economy (Google Trends, 2017)*




The increased interest in the sharing

economy is related to the dissemination of the internet and digital technologies. Codagnone and Martens (2016) note that “citizens have found ways to organize resource sharing for millennia” (p. 4). In Zurich, car sharing was organised and operated by community-based not-for-profit cooperatives during the 1940s already. However, information cost was high in the analogue era, which prohibited the scaling up of such organisational forms. With the rise of new technologies, information costs fell and online sharing activities have been rapidly spreading since then (Codagnone & Martens, 2016).

In summary, the sharing economy can be described as a socio-economic concept that summarizes social components, such as the willingness of consumers to become producers by sharing goods or offering service to other consumers, and economic concepts, such as online platforms that enable the exchange and interaction needed for these transactions. Although the sharing economy is a development that neither exclusively nor intensively focuses on the electricity market, it has three relevant influences on the electricity market’s development.

Firstly, the sharing economy shows that alternative, collaborative-focused business models can be successful (Lombardi & Schwabe, 2017; Plewnia & Guenther, 2017). From a conceptual perspective, this facilitates a transfer of these models to the electricity market. From an operational perspective, it eases the implementation of such models as investors are more willing to fund innovative, collaborative business models.

Second, the development of the sharing economy changes the overall perception and behaviour of customers. Consumers are becoming used to now owning an asset, but retrieving the needed service from another consumer (Del Rowe, 2016, p. 24). Similarly, the population is becoming more open to share the assets they own with other consumers (Rousselet, 2014, p. 25). This facilitates the emergence of sharing-economy-based models in the electricity market, as their acceptance among end-consumers is already established through existing collaborative services.

Third, the rise of the sharing economy also increases acceptance of collaborative approaches among existing supply-sided market participants. Valdman (2016) points out that it is not the technical possibilities that prevent the electricity market from evolving further, but that instead it is the “sociology, not the physics, that stands in our way” (¶ 3). Hence, it is important that existing experiences prevent over-regulation and facilitate an open approach to collaborative business models.

## 3.2 The blockchain and distributed ledger technologies

This section provides an introduction to blockchain technology, starting with the functional principles before offering a broader overview of blockchain development and its application potential.

### 3.2.1 Functional principles

Blockchain technology is a special form of a distributed database. All participants in the network share a consistent copy of the database; not having a central server is a distinct feature of distributed databases. Moreover, network participants can conduct peer-to-peer transactions, meaning that transactions, e.g., online payments, can be transferred directly from one person to another without an intermediary or central authority such as a central bank. In place of the intermediary, participants share the responsibility to verify the legibility of the transaction using a pre-agreed-upon consensus mechanism. Figure 3 illustrates the procedure of verifying and executing payment transactions through a bank versus a P2P network.

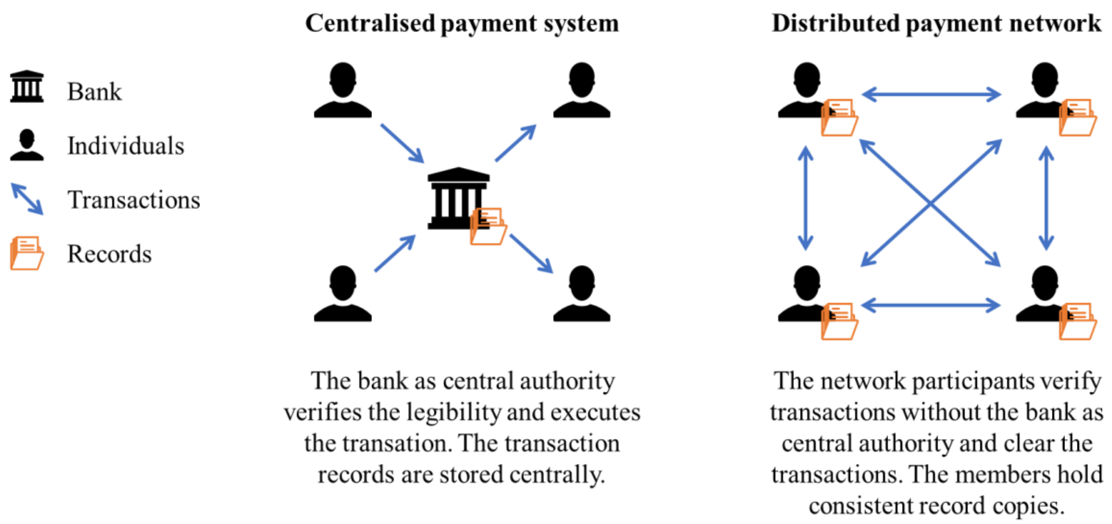



*Figure 2: Centralised vs. distributed payment transactions*

In a centralised payment system, only the bank holds the list of all transaction records, for example who transferred money to which account. In comparison, in a distributed P2P payment network all participants are connected with each other via the internet and everyone has consistent copies of the list of records. This allows the participants to directly share information or initiate transactions between each other. The list of transaction records equates to a ledger. Because of this, blockchain technology is more formally also called distributed ledger technology, as the previously centralised ledger is now replicated and distributed across the network (see Appendix A).

In short, blockchains enable disintermediation by building a distributed and replicated ledger among all the users of the blockchain. The following section explains in more detail how the transaction process works and identifies the key distinctions and features of the blockchain compared to other databases. This serves as a basis for the use cases where the blockchain could be applied or the solutions it could enable.

### *The transaction procedure*

The above-mentioned participants in a blockchain network are, to be more precise, computer systems connected to the network. These serve as so-called nodes in the network. Each node can initiate transactions. The process of validating and recording transactions is best exemplified by a currency transaction:

1. A network participant, A, wants to initiate a transaction of 50 currency units (CU) to another participant, S.
2. The transaction record of the intended transaction contains A's node identification, the transaction matter, and Simon's node identification. The transaction record forms a so-called 'block'.
3. Next, the block is broadcast to all nodes within the network to let them know of the transaction request by A.
4. The remaining network now checks, by means of a pre-agreed-upon consensus mechanism, whether A has sufficient funds in her online wallet to execute the transaction. If she has a minimum of 50 CUs, the network approves and validates the transaction.
5. To make the transaction indelible by network participants, the transaction record is registered in the list of all past records. In a figurative sense, the block is added to the chain of other blocks. This then forms the blockchain.

6. Lastly, the 50 CUs are transferred from A to S. Their CU balance is updated in their online wallets.

Looking into the transaction process, three more things about blockchain technology can be learned. First, the technology uses a consensus mechanism in order to validate a transaction. This is a requirement to be able to disintermediate the transaction process from the hands of a central authority. The different validation methods are discussed later. Second, the blocks, which are added successively following validation, remain transparent and verifiable to the network participants. This follows from the mechanism of the distributed ledger as all network participants, or the computer systems to be precise, keep a copy of the transaction records. Third, transactions are immutable as a consequence of all participants keeping a copy and thereby having proof of past transactions. However, this immutability is not absolute. If the network participants decide to change some recorded information, they need to agree to do so according to the pre-agreed-upon consensus protocol. This means that a single node cannot make changes but the whole network is capable of doing it, conditioned on the respective validation method, i.e., the consensus mechanism. How the blockchain ensures validity and immutability of the added information will be described in the following.

### *Behind the blockchain*

The procedure introduced above has a distinct mechanism to identify and store transaction[4] data. In addition, even though the all participants in the P2P network can monitor all transactions, the transaction data themselves are private and only accessible by the two parties involved in the transaction, as explained below.

Each piece of transaction data has a metaphorical digital fingerprint to identify it uniquely. For this purpose, cryptographic hash functions are used to transform input data (such as the transaction matter and the node’s identification) into a unique combination of numbers and letters (the ‘digital fingerprint’). Bitcoin uses the SHA-256 hash function, which means that any input is transformed into a hash value with a length of 256 bits. For example, the hash value of the word ‘hello’ with a small ‘h’ (Movable Type, n.d.) is

2cf24dba5fb0a30e26e83b2ac5b9e29e1b161e5c1fa7425e73043362938b9824

[4] Here, the term ‘transaction’ is used in the broader sense of a transfer of ownership.

The hash value of the word ‘Hello’ with a capital ‘H’ (ibid.) is

185f8db32271fe25f561a6fc938b2e264306ec304eda518007d1764826381969

Hash functions are one-directional, meaning that the input value cannot be back-traced from the hash value; furthermore, if the input data are changed, for example, by using a capital ‘H’ instead of ‘h’, the hash value is unpredictably changed by the hash function (Drescher, 2017). This implies two advantages. First, the stored and visible hash value on the blockchain does not unveil the transferred ‘content’. Second, if one network participant wanted to change a given property of the transaction (recipient or transferred content), the hash function would automatically change the hash value and thereby unveil the intended change. This way, malicious attacks are (very likely) uncovered immediately.

Transaction data that needs to be added to the blockchain then goes through the ‘mining’ process. In this process, the miner puts the transactions that need to be validated, as well as a timestamp, a reference to the last block in the chain, and an alterable input field (the so-called nonce) into the hash function. The output—a hash similar to the hash presented above—needs to fulfil certain criteria in order to be chained to the blockchain and thereby be validated and publicly available. As of December 2017, this criterion is that the hash starts with 18 zeros. As the hash function might not meet this criterion, miners need to use a trial and error approach by changing the nonce until their hash satisfies the criterion (as hashes are one-directional functions, it is not possible to reverse-engineer a hash with the information that is to be validated and the required numbers of zeros). As this needs much computational power and electricity, miners are compensated in new (mined) bitcoin for every block that they successfully add to the blockchain.

When joining a network, each node is assigned a unique, two-piece identification: a public and a private key. The public key is shared with the network, comparable to a person’s bank account number. The public key is thus used to identify accounts. The private key is used to sign and authorise transactions and is comparable to a person’s manual signature or password. During the transaction process, the public keys are used to identify both involved parties. The private key is fundamental to authorising the transfer of ownership (Drescher, 2017).

## *Validation methods*

As mentioned above, the approval of transactions is done collectively. This process is also defined by a set of rules, which are referred to as consensus protocols. They encompass which additions can be made to the blockchain, who decides and creates them as well as to what extent the additions are made. Presently, there are two types of consensus protocols: Proof of Work (PoW) and Proof of Stake (PoS).

PoW is the most commonly used validation method and relies on the mining process (PwC, 2016, p. 7). The effort required to solve a puzzle is called Work, while the solution is called a PoW, meaning that if the solution is known, this proves that someone did the work to find the solution. This process is also called mining. In the blockchain, PoW or mining is required to add any new blocks to the chain. Hereby, the chain with the most blocks is the correct blockchain because it comprises the most work. In a scenario in which a node would like to make modifications to the chain, the node would have to redo all of the subsequent work, as the modifications would invalidate the existing blocks and the ones being added permanently. Hence, this node would have to do the work faster than at least 51% of the other mining nodes together in order to validate its modification; this is referred to as the 51% attack. The attack would require computational power that is larger than that of the other mining nodes combined (Follow My Vote, n.d.).

The PoS protocol was developed to improve some shortcomings of the PoW. With PoS, no work is required, but the network participant must hold a stake in the blockchain system in the blockchain instead of computational power (Castor, 2017). A stake may, for instance, represent a currency balance that somebody owns. The higher the balance of a specific node, the more power the node has in building a block. This is based on the intuition that major stake-owners want to keep their stake as safe as possible from attacks and therefore foster secure and frictionless block production. For a 51% attack to happen, a node must grab hold of 51% of the stake within the network. Acquiring such a stake is expensive for the attacker, since prices rise with higher demand (in case of currencies) (Follow My Vote, n.d.).

## *Accessibility options*

A blockchain can be private or public (Garzik, 2015, p. 11). In a public blockchain everyone can join the network without a control mechanism. Hence, there is also no operator who controls the system or charges an additional margin. In comparison, public blockchains have an operator who controls who gets access and who doesn’t (Gramoli, 2016, p. 3). Private blockchains work under the same principles as a public blockchain with the difference of restricted access and a selection of trusted nodes that verify transactions. Hence, in comparison to a public blockchain, the centralization saves transaction costs, as less effort is needed to verify a transaction. For the operator, these system provide the advantage that processes can be automated and made more efficient, but the provider has the power to control accessibility and charge fees for the provided service (PwC, 2016, p. 12). Private blockchains are especially interesting for corporations whose business model is in danger of getting disrupted by the blockchain technology, such as banks. Using private blockchains they can on the one hand benefit from automating their process and on the other hand can still charge a fee for the service as they continue to utilize their existing customer base.

### 3.2.2 Development and use cases of the blockchain

Blockchain technology was first introduced as a digital payment system. More specifically, Satoshi Nakamoto[5] introduced the cryptocurrency bitcoin in 2008 (Nakamoto, 2008). The initial bitcoin movement that occurred in the years after the currency's introduction is commonly referred to as Blockchain 1.0. Expanding on Blockchain 1.0, which deals with the decentralisation of money and payments, Blockchain 2.0 encompasses the development of further applications which may benefit from decentralised infrastructures within markets (PwC, 2016, p. 6). As Swan (2015) states, "the key idea is that the decentralized transaction ledger functionality of the blockchain could be used to register, confirm and transfer all manner of contracts and property" (p. 10). Possible use-cases move beyond crypto currency and include a broader range of application possibilities. The following provides an overview of the most promising use cases of blockchain technology.

#### *Smart contract*

By extending the usage of cryptocurrencies, the blockchain can utilise its core function: Validating transactions if certain conditions are met (for example, validating a bitcoin payment if there is enough balance). Ethereum, a blockchain that aims to further advance in correcting the shortcomings of bitcoin, focusses on using the advantages of blockchain technologies such as decentralised validation methods to enable smart contracts (PwC, 2016, p. 14). Smart contracts are pre-defined and formalised agreements executed and enforced by

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[5] Satoshi Nakamoto is a pseudonym; the identity of the inventor or developer is not known.

code across all network nodes in an autonomous and decentralised manner (Swan, 2015). This is possible by specifying if-then conditions to trigger transactions. While such automation processes have existed for a long time (for example, automatic bill transfers at the end of each month), by putting the conditions on the blockchain, its validation is not dependent on a single entity. The blockchain also depicts the settlement of the smart contract and can assess whether the agreed terms have been met (Drescher, 2017, p. 240). Hence, smart contracts based on a blockchain remove the middleman to verify contracts and enable automatic settlements based on the conditions agreed by the parties involved. By combining several conditions, a smart contract could, for example, automate the sale of a security if a certain price target is hit and directly settle the transaction in cryptocurrency.

### *Ownership documentation*

The blockchain is applicable to various modes of exchange: Inventory and asset registries, as well as both hard and intangible assets. The process of registering any asset as a digital asset on the blockchain is called tokenisation (Cameron-Huff, 2017). Although it is not possible to physically store tangible assets in a blockchain, its record of ownership can be registered there. As described above, one of the main advantages of the blockchain is that once a record is on the blockchain, it cannot be altered, as the other nodes in the network would detect this (Drescher, 2017, p. 65). Hence, if ownership over an asset is registered on the blockchain, the ownership records can only be changed with the current owner's private key. This entails two use cases. First, it eases the transfer of ownership. While intermediaries used to be necessary to check whether the seller of an asset was its actual owner, this is now done by the nodes of the network. The verification is furthermore completed within seconds, without any paper trail and with the possibility for instant settlement (e.g. using a cryptocurrency). Second, it simplifies the shared ownership of physical assets. While it is easy to physically divide some assets (e.g. a 1 kg gold bar into two 0.5 kg gold bars), this is not possible with many assets that are central to today's society (e.g. a production machine or an airplane). Although the shared ownership of such assets is not new (consider a corporate shareholder), establishing shared ownership on a blockchain brings additional advantages. Not only does it simplify the ownership transfer process as described above, it also allows combining the ownership records with blockchain-based smart contracts. For example, a shared car ownership can be managed in such a way that the use of the car is continuously tracked and transactions are settled directly and automatically among the users of the car and the owners (EY, 2017).

### *Distributed transaction records*

One characteristic of the blockchain that depicts a use case is the distributed storage of all transaction records. As every transaction is added to the block chain, every participant can monitor and back-trace all transactions. Practically no other market provides such transparency about its transactions without any additional information-sharing costs for the market participants and almost in real time. These transaction records can be utilised to improve the flows of goods. For example, a producer can track the consumption of its input factors and check their source of origin in order optimise its ordering mechanism and supply chain (Deloitte, 2017, p. 16). A producer could also automate its billing process based on the transaction records with its customers (Deloitte, 2017a).

## 3.2.3 Limitations of the blockchain

Although the blockchain has many advantages and the potential to disrupt a variety of industries, the technologies also faces some limitations that might hinder or slow down wide-spread usage.

First, the wide-spread usage of the blockchain is limited by its maximum throughput (Beck, Czepluch, Lollike, & Malone, 2016, p. 12; Swan, 2015) (Croman et al., 2016, p. 1). While payment technologies such as VISA are able to process up to 47,000 transactions per second (Beck, Czepluch, Lollike, & Malone, 2016, p.12), blockchains throughput is usually more limited. For example, bitcoin can only process a maximum of seven transactions per second. This is due to the size limit of each processed block. Although it would be technically possible to increase the size of the blocks, such updates are unpopular among large parts of the bitcoin community, especially miners (Brandon, 2017). They are concerned that with increased size of the blocks miners with limited bandwidth are disadvantaged.

Second, the decentralized approach of the blockchain brings disadvantages as the blockchain grows. As every full node needs to process every transaction, the inter-node traffic increases logarithmically with every added node – leading to an increase in latency as more nodes are added (Kasireddy, 2017). Hence, the processing latency not only limits the general application opportunities of the blockchain (Swan, 2015; Beck, Czepluch, Lollike, & Malone, 2016), but the limitation also become more apparent as a blockchain grows.

Third, although the storage of all past transaction on the blockchain leads to a large data size and requires large bandwidth. If the bitcoin blockchain were to increase its throughput to

VISA standards, the blockchain would grow by 1.42 PB/year (Swan, 2015, p. 82). Through requiring more resources, an increase in size and bandwidth would ironically promote centralisation.

Fourth, blockchain transactions are resource and energy-intensive ( Beck, Czepluch, Lollike, & Malone, 2016, p. 12; PwC, 2016, p. 15; World Energy Council, 2017, p. 5). Croman et al. (Croman et al., 2016, p. 4) estimate the cost per confirmed transaction be between USD 1.4-2.9. These costs are mostly driven by the energy-intensive mining process. Compared to the VISA network, bitcoin uses 20,000 times more energy per transaction (Brosens, 2017). This is due to the decentralization that requires all node to process a transaction. Although other blockchains such as Etherum require less energy, compared to centralized system their energy consumption is still more than 1000 times higher (Brosens, 2017).

# 4. Methodology

This chapter describes the methodology used to evaluate the potential impact of the blockchain on electricity markets. The electricity market as defined here includes electricity market design and the current market players and their roles.

The objective of the thesis is to answer the research questions stated in the introduction. To recap, the questions are listed below:

- What are the existing blockchain-based business models within the electricity market?
- How do these business models affect the electricity market and the value chain?
- What needs to be considered when implementing a blockchain-based P2P energy-trading platform?

In order to determine innovative and disruptive patterns caused by the blockchain to the electricity market, three steps are required: First, the status quo of the electricity market has to be described. The electricity market was already introduced in Chapter 2, but in the analytical part the focus lies on describing the business models used by different actors. Second, an analysis of the blockchain applications which are new to the electricity market is done. Taking new blockchain applications into account, the third steps identifies the effects of their business models on current electricity market design and the effect on the roles of the market players (as described in Chapter 2 and in step one of the analysis below).

## 4.1 Business-model concepts

In order to identify a business-model framework for the present analysis, a brief literature review of research on business-model definitions and components is conducted.

Business models in general try to explain how a business works. Research on business models has received growing attention in recent years, particularly with the rise of e-business and the internet in general; the majority of research addresses business models within e-business (Amit & Zott, 2001; Dubosson-Torbay, Osterwalder, & Pigneur, 2002; Onetti, Zucchella, Jones, & McDougall-Covin, 2012; Timmers, 1998). The emergence of business-model theories and concepts in parallel with the emergence of the era of the internet has also been noted in the literature (Teece, 2010). However, general business-model concepts which are not solely focused on e-business have also emerged. There is as of yet no consensus regarding terms and the usage of business-model concepts (Osterwalder, 2004). According to Teece (2010, p. 179), “a business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value”. Amit & Zott (2001, p. 511), on the other hand, describe the business model as “the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities”. While strategy is about formulating and implementing a plan for the future development of an organisation to gain a competitive advantage, a business model is necessary but not sufficient to execute a strategy (Demil & Lecocq, 2010; Teece, 2010; Zott, Amit, & Massa, 2011). In addition to these holistic definitions, some authors showcase elements or building blocks of business models. For instance, Osterwalder (2004) has identified the nine building blocks of a business model; Chesbrough (2010) describes seven functions that a business model should fulfil; Yunus et al. (2010) discusses three; and Gassmann, Frankenberger and Csik (2014) discuss four dimensions of a business model. Nevertheless, authors tend to agree on the core components of a business model. Below, an overview of the literature regarding corresponding notions in business-model definitions is provided. Gassmann et al.’s (2010) four dimensions of a business model are used as the basis, as they include, in addition to the elements in Lehmann-Ortegas’s model[6], the identification of the target customer segment, which simplifies the understanding of the proceeding business-model elements. Figure 7 shows Gassmann et al.’s business model with its four dimensions and the corresponding key questions to identify and define the aspects of the business model. Definitions and explanations given by other authors are mapped according to these four dimensions in order to validate the business-model dimensions as a sufficient way to identify an organisation’s business model. Prior to this, it should be

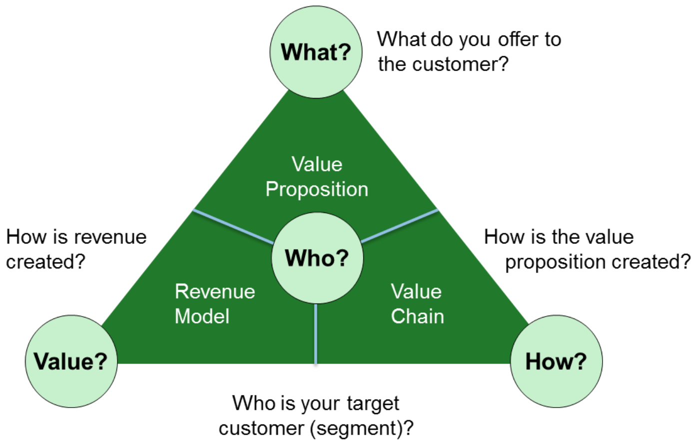


*Figure 3: Business-model definition – the magic triangle (Gassmann et al., 2010)*

[6] The three business-model dimensions according to Lehmann-Ortega are: value proposition, value architecture and profit equation.

noted that business-model definitions and dimensions are to a great degree centred around value. According to Porter (1985, 38), value is defined as ‘the amount buyers are willing to pay for what a firm provides them’.

A target customer or market segment is whoever an organisation ultimately addresses its product or service offerings to. Knowing the target customer is the foundation for outlining the value proposition.

| Target customer | | |
|---|---|---|
| Market segment | “The users to whom the technology is useful and for what purpose” (p. 533). | Chesbrough & Rosenbloom (2002) |
| Target customer | Who the target customer (segment) is (p. 2) | Gassmann et al. (2014) |
| Customer segment | “the different groups of people or organizations an enterprise aims to reach and serve” (p. 20) | Osterwalder & Pigneur (2010) |

*Table 4: Literature overview of target customer definitions in business models.*

The dimension ‘value proposition’, as summarised in table 5, ‘describes what is offered to the target customers’ (Gassmann *et al.*, 2014). In the literature, this aspect of a business model is the most commonly agreed on.

| Value proposition | | |
|---|---|---|
| Value proposition | “The value created for users by the offering” (p. 533) | Chesborough & Rosenbloom (2002) |
| Value proposition | “What is offered to the target customers” (p. 2) | Gassmann et al. (2014) |
| Value proposition | “The Value Propositions […] describes the bundle of products and services that create value for a specific Customer Segment” (p. 22) | Osterwalder & Pigneur (2010) |
| Benefits | “A description of the potential benefits for the various business actors” (p. 4) | Timmers (1998) |

*Table 5: Literature overview of value proposition definitions.*

The value chain orchestrates all the activities and resources of an organisation in order to create and distribute the product or service offering defined in the value proposition (Chesbrough & Rosenbloom, 2002). The terms used by authors diverge the most for this dimension, although the authors still describe similar aspects around an organisation’s activities to create value.

| Value chain | | |
|---|---|---|
| Value creation | "The exploitation of business opportunities" (p. 493) | Amit & Zott (2001) |
| Structure of the value chain | "Value chain within the firm required to create and distribute the offering" (p. 533) | Chesbrough & Rosenbloom (2000) |
| Value chain | How the value proposition is created (p. 2) | Gassmann et al. (2014) |
| Key activities | "the most important things a company must do to make its business model work" (p. 36) | Osterwalder & Pigneur (2010) |
| Value creation | "how a business creates and delivers value to customers" (p. 173) | Teece (2010) |
| Architecture | "An architecture for the product, service and information flows, including a description of the various business actors and their roles" (p. 4) | Timmers (1998) |

*Table 6: Literature overview of value chain definitions in business models.*

Finally, value capture addresses the financial aspect of the business model, i.e., how it generates revenue. Even though most authors focus on revenue linguistically to define this dimension, it also includes the cost structure (Chesbrough & Rosenbloom, 2002; Johnson et al., 2008).

| Value capture | | |
|---|---|---|
| Architecture of the revenues | "How a customer will pay, how much to charge and how the value created will be apportioned between customers, the firm itself and its suppliers." (p. 534) | Chesbrough & Rosenbloom (2002) |
| Revenue model | How the revenue is created (p. 2) | Gassmann et al. (2014) |
| Revenue stream | "The Revenue Streams […] represents the cash a company generates from each Customer Segment" (p. 30) | Osterwalder & Pigneur (2010) |
| Value capturing | "the manner by which the enterprise […] entices customers to pay for value" (p. 172) | Teece (2010) |
| Revenue sources | "the sources of revenues" (p. 4) | Timmers (1998) |

*Table 7: Literature overview of value capture definitions in business models.*

This literature review gave a brief overview of similar definitions of business models, which in their essence address the four dimensions outlined by Gassmann *et al*. (2014). In order to reduce complexity in the following analysis, Gassmann's business-model definition is used, as it is at the same time sufficiently comprehensive to capture and also to evaluate business models across different organisations.

## 4.2 Case-study format

In line with the research question, this paper focuses on the analysis of business models that implement blockchain technology to offer services along the electricity value chain. In order to draw compelling conclusions about the potential and impact of the blockchain on the energy market, the case-study is structured into five steps and leads to an analysis of multiple cases:

1. First, the case-studies for the business-model analysis are gathered and selected. This is done through a systematic database search and is cross-checked against blockchain project reviews in grey literature within the field of energy business. (see secion 4.2.1 and Appendix C)
2. The selected case-studies are then described following the business-model dimensions identified in section 5.1. The business-model dimensions serve as a conceptual framework for the analysis to understand blockchain applications. (see Appendix D)
3. Based on the business-model description, relevant characteristics of the business models are identified and grouped into categories which describe the business-model dimensions in greater detail.
4. The cases are reviewed a second time to apply the categories and characteristics. (see Appendix E)
5. Connections between and within the categories are assessed and business-model patterns are identified to construct archetypes. These archetypes are then outlined in section 5.2)

### 4.2.1 Case-study selection

The desk research process to collect applicable case studies started with building a longlist of projects within the energy field. The selection process of case-studies, which are further analysed in the paper, was as follows:

1. A longlist of potentially relevant blockchain projects within the energy sector was compiled. (see Appendix C)
2. The projects on the longlist were reviewed for their applicability for further analysis. For this purpose, some criteria were defined to examine the projects and available information at a surface level. The remaining projects form the shortlisted case-studies for the business-model analysis.

Below, the two components of the case-study selection are further elaborated.

The longlist is based on databases and the most recent publications on energy blockchain use cases. First, the Crunchbase start-up and company database (Crunchbase, 2017) was screened for organisations. The basic Crunchbase dataset search allows for two search filters. Therefore, the search was conducted by using the following key word pairs seen in table 8.

| Database | Applied search filters or tags | Results |
|---|---|---|
| Crunchbase | Blockchain & energy | 36 |
| | Blockchain & electricity | 9 |
| | Blockchain & solar | 6 |
| | Blockchain & renewable | 5 |
| | Distributed ledger & energy | 2 |
| State of the DApps | #energy | 8 |
| | #renewable | 2 |
| | #solar | 1 |
| | #electricity | 1 |

*Table 8: Overview of database search criteria and results.*

The results for the applied search filters overlapped significantly and were consequently condensed to a preliminary longlist version. Second, the database State of the DApps was screened. This database categorises and showcases projects built on the Ethereum Blockchain (State of the DApps, n.d.). The search was conducted using tags individually. The majority of the projects had already been identified by the Crunchbase search, but some new cases were added to the longlist. Third, exemplified use cases from a PwC report on blockchain in the energy market was used to add a some case studies to the list (PwC, 2016). The longlist encompasses around 50 case which were then reviewed for their applicability (see Appendix C).

### 4.2.2 Identified categories and characteristics for business model analysis

The process of describing projects according to the four business-model dimensions *target customer*, *value proposition*, *value chain* and *value capture* (see Appendix D) revealed characteristics specifically relevant to the electricity market. This step is pertinent to defining blockchain-based business-model archetypes. The following therefore presents the overarching categories and describes the characteristics of each.

Starting with *target customer,* two subcategories are useful to distinguish between cases: customer group and network size. First, the customer group is taken for granted to be analysed in the context of the target customer dimension. The customer groups in the analysed cases encompass typical market participants as well as ones relatively new to the energy market:

- Energy **consumers** are mostly private households but also residential and commercial consumers.
- Energy **producers** are, in the cases studied, mostly small- to large-scale producers with DER.
- Energy **prosumers** are households with RES for self-consumption and surplus energy production which does not exceed their consumption over the year.
- **Utility companies** operate the regional or local infrastructure and read the consumers' electric meters.
- **System operators** establish and maintain the transmission and distribution infrastructure.
- **Private investors** are individuals who want to invest their money in assets and expect a future return.
- **Property owners** include individuals, communities or commercial actors who have spare roof area or land on which solar PV could be installed.

It should be noted that the term ‘customer’ here refers to a broad range of customers who could potentially include every energy-market participant. Second, the scope of business operations in terms of the targeted location is an important aspect in addition to the customer group itself. Here, a distinction into three levels can be made:

- **Local**: The projects are implemented on a local level, i.e., within communities or municipalities.
- **Regional**: Regional projects are not restricted to communities or municipalities and aim to be implemented on a national or, e.g., European level.
- **Global**: Projects at a global scale can technically reach customers irrelevant of their geographical location.

The customer group and the scope help to specify the target customer and the outreach of the projects.

The business-model dimension *value proposition* addresses, by definition, what is offered to customers or, more precisely, what values are created for them. The characteristics of this dimension can be classified into four categories: the first two are of financial value, while the latter two offer non-financial value.

- **Revenue**: Customers can be offered the opportunity to gain additional revenue by engaging with a particular project, for instance by offering their surplus energy to a trading platform. Potential revenue sources for customers are generated by the sale of electricity, the sale of RECs or through rent by getting a return on investments/rent.
- **Costs**: Some projects’ value lowers costs for customers. Lower electricity costs for end-consumers can be achieved by lower electricity prices or higher energy efficiency. Utility companies can benefit from lower administrative costs.
- **Transparency**: The value of transparency is visible in three ways. First, projects can grant energy consumers complete transparency over the components of their energy bills. Second, in some cases energy consumers can have insight into the energy mix they are procuring. Third, energy consumers can in some instances gain insight into their real-time energy consumption.
- **Flexibility**: Flexibility is reflected in the way that customers can freely modify or adapt variables of the project’s service offerings. Among the cases studied, three

possibilities were identified. First, one case highlighted flexibility regarding entering and leaving the contract any time. Second, energy consumers can freely choose their desired energy mix, thereby mostly making a trade-off decision between locally and/or green energy and traditionally-sourced energy with lower costs. Third, energy consumers can freely choose between different payment methods.

The third dimension, *value chain*, defines how the value proposition is delivered to the target customers. In order to fully relate it to the value chain, four categories are defined which summarise the characteristics:

- **Business processes/operations**: This category describes how a project is involved in/set up to deliver value. For instance, a project can facilitate energy trading via a platform or buying and reselling the energy. Moreover, processes such as tokenisation and monetisation can be used. Value for the customers can also be generated by enabling crowdfunding or leasing.
- **Technology**: This category identifies the soft- and hardware that projects utilise. First, the software component clarifies what kind of blockchain is used and whether methods such as artificial intelligence are utilized by a project. Second, the hardware component identifies whether the projects use or provide special hardware to deliver value to customers. Among the hardware identified are smart meters and smart agents. The projects do not provide other infrastructure such as solar PV.
- **Control & energy network**: This summarises the core operations with regard to the energy-market network. The characteristics identified encompass supply curves and demand forecasting, grid stabilisation and balancing, as well as demand response and demand-side management.
- **Financing**: Projects can be differentiated by how they are funded. Three models were identified. First, some projects originate from companies or corporate partnerships. In these cases, it is assumed that the funding is provided by corporate venture capital. Second, some blockchain projects originating from start-ups choose traditional start-up funding by venture capital. Third, a new funding method that has

emerged in parallel with blockchain-based business is raising funds through an Initial Token Offering (ITO)[7].

Lastly, the dimension *value capture* specifies how businesses are generating revenue. The projects analysed had the following revenue sources:

- **Transaction fee**: A transaction fee can be charged on every energy and payment transaction. It can be applied as a percentage of the transaction value or as an absolute amount.
- **Subscription fee**: A subscription model applies when the customer is charged a specific amount periodically.
- **One-off**: One-off revenue describes a non-recurrent payment for a service or product.
- **Licensing**: The licensing model applies to software solutions. By offering a license to customers, businesses offer the right to use the software for a predefined period. The licensing fee can occur either periodically, in the form of a one-off fee or it can be consumption-based.
- **Open source**: Some cases used software that is free of charge.

[7] ITOs are similar to a traditional initial public offering (IPO) of a company. In an IPO, a company is raising capital by selling shares of the company. Similarly, in ITOs, startups are selling tokens for fiat money or cryptocurrencies. The tokens that are sold can be used to obtain the services that the company is offering or they can be re-sold to other customers at a higher price.

Table 13 provides an overview of the identified categories and their characteristics, which are applied to identify the business models of the cases studied.

| Target customer | Value proposition | Value chain | Value capture |
|---|---|---|---|
| **Customer group**<br>- Consumers<br>- Producers<br>- Prosumers<br>- Utilities<br>- System operators<br>- Private investors<br>- Property owners<br><br>**Network size**<br>- Local<br>- Regional<br>- Global | **Revenue**<br>- Sale of electricity<br>- Sale of RECs<br>- Rent / RoI<br><br>**Costs**<br>- Electricity costs (prices or efficiency)<br>- Administrative costs<br><br>**Transparency**<br>- Energy-bill components<br>- Procured energy mix<br>- Real-time energy consumption<br><br>**Flexibility**<br>- Contract<br>- Energy mix and price<br>- Payment method | **Business processes/operations**<br>- Energy-trading platform<br>- Buying and reselling energy<br>- Tokenisation<br>- Monetisation<br>- Crowdfunding<br>- Leasing<br><br>**Technology**<br>- Software (blockchain, AI)<br>- Hardware (smart agent, smart meter)<br><br>**Control & energy network**<br>- Forecasting<br>- Grid stabilisation and balancing<br>- Demand response<br>- Demand-side management<br><br>**Financing**<br>- Corporate venture<br>- Venture capital<br>- Initial token offering | **Revenue sources**<br>- Transaction fee<br>- Subscription<br>- One-off<br>- Licensing<br>- Open source |

*Table 9: Categories and characteristics identified among the cases studied, organised by business-model dimension.*

# 5. Blockchain-based business models within the electricity market

This chapter summarises the analysis conducted after identifying the categories and characteristics pertinent to the business-model dimensions. First, section 5.1 provides an overview of the identified business-model archetypes following Appendix D and E. Second, the business-model archetypes are each outlined in section 5.2. Parallel to this, the consequences for the energy market are elaborated for each business-model archetype. Third, the findings are consolidated and discussed in section 5.3.

## 5.1 Identified business-model archetypes for blockchain-based projects within the energy market

To identify business-model archetypes, the shortlisted cases from Appendix A were first outlined according to the four business-model dimensions. The results of this step can be seen in Appendix B and they formed the foundation for identifying the characteristics specific to the cases studied. Subsequently, the cases were reviewed again to map and specify their characteristics. The outcome of this procedure can be seen in Appendix C. Next, the cases that have similar sets of characteristics were grouped together to form business-model archetypes. Consequently, seven business-model archetypes were identified from 22 cases at hand. The following graph provides an overview of the archetypes, which are: retailer, REC-incentive scheme, proof-of-green-power procurement, OTC-trading platform, flexibility-trading platform, crowd-sale/funding platform and P2P energy-trading platform.

## 5.2 Description of business-model archetypes and their impact on the electricity market

### 5.2.1 Retailer

*The business model*

The retailer archetype resembles the existing electricity-retail business model. The target customers are residential and commercial electricity consumers. The value proposition to the customers centres on offering a lower electricity price and generating revenue through energy arbitrage. In addition, transparency and flexibility are provided for example through having complete insight into energy charges and bill components or the option to enter and leave the energy contract without restrictions. Moreover, consumers have superior choice over the configuration of their energy mix. They can then balance their preferences regarding the energy mix and their willingness to pay. Within the value-chain dimension, the two representative cases, Drift and Grid+, differ slightly. Drift purchases energy directly from its network of independent energy generators following its supply-and-demand forecasting, while Grid+ buys electricity from the wholesale market. Both sell energy to their customers and collect transmission and distribution charges for the DSO. Technology-wise, Drift operates on a distributed ledger. Grid+ uses the Ethereum blockchain and additionally takes advantage of a smart agent. The agent automates billing in real-time after customers make a prepayment on the digital wallet that is associated with the smart agent. In addition, the agent can control customers' connected devices such as energy storage units or smart thermostats. This way, Grid+ enables customers to shift consumption and arbitrage energy prices, thereby contributing to grid balancing. The revenue sources of the two services differ as well. Drift in fact passes on the wholesale price to the customers, who in return pay a weekly subscription fee of $1. Grid+ charges a transaction fee with a mark-up of 20%. In addition, the smart agent presumably costs a minimum of $50. Grid+ not only operates as a retailer on its own, but also licenses its soft- and hardware to interested utility companies and retailers. Even so, at the core of their business model, the operations of the two cases resemble an electricity retailer.

### *Implications for the electricity market*

Blockchain-based retailers are innovating within the energy market on three fronts. First, Drift is replacing the intermediary and directly sources energy from producers to sell it to customers. This gives it a competitive advantage over other retailers by taking advantage of the digitalisation trend (see Chapter 2) and cutting administrative costs in response to financial pressure in the energy market. Consequently, the retailer is able to offer the commoditised product at a lower price than other retailers. Second, the option to freely adapt one's own energy mix reflects a high degree of customisation, whereas prior to this customers might have been able to choose between regular utilities or green-power retailers, but nothing in-between. Third, the retailers collect customer payments at a higher frequency than the regular monthly invoice. This way, the companies face lower risks of not having customers pay their energy bills and optimize their cash-flows.

The retailer takes advantage of or is enabled by the blockchain technology especially in the first and the third area. On the one hand, linking a network of producers as well as consumers on a blockchain-based platform allows the retailer to better aggregate and forecast demand as well as to track the available generation capacity of the suppliers. On the other hand, blockchain simplifies accounting for energy transactions and automates the billing process through smart contracts. Hence, the key blockchain characteristics which are taken advantage by the retail model of are disintermediation, transparency and distributed ledger.

### 5.2.2 Renewable energy certificates

#### *The business model*

This type of blockchain applications is meant to incentivise and reward renewable energy deployment. The target customers are solar-energy producers, prosumers, consumers as well as miners. The incentive scheme can be implemented on a global scale. The value proposition for producers and prosumers is that for each generated kWh or MWh of electricity, they get a unit of a cryptocurrency or a token (in the two cases studied, the rewards are referred to as coins). The coins serve as proof of the renewable energy generated. In other words, they resemble RECs and provide a transparent and verified record of green energy production. Miners who process the transactions receive a 2% interest per transaction for their efforts. The recipients can use the coins to buy electricity for the same rate or can redeem them against fiat currency. Interested consumers can purchase the coins and buy a corresponding amount of electricity from the producers or prosumers. In this way, the consumer is guaranteed to procure electricity from their chosen source. The main value-chain process for issuing coins for the energy generated relies on tokenisation, which can be done in two ways. First, one case implements the incentive scheme on the Ethereum blockchain and tokens are hence created on the basis of smart contracts. Second, another case runs on a public blockchain similar to bitcoin and issues coins. In other words, the latter case relies on miners, while the former case does not. This is also related to the fact that the latter project was developed to be open source. The revenue model of the first project (NRGcoin) is not publicly disclosed and depends on the implementation goals of the interested parties.

### *Implications for the electricity market*

First, the coins serve as incentives for producing solar energy. In regions where no renewable-energy subsidies or similar support schemes have been implemented, the coins can minimise the pay-back time for investment in the solar PV. With this mechanism, the global deployment of renewable energy can be advanced. Second, the blockchain-based issuing mechanism makes the intermediary redundant as the process is verifiable and the coins are directly linked to the solar energy generated. In this way, the currently complicated REC-issuing system can be simplified by tokenising the generated energy in real-time. Overall, this model is aligned with global goals to mitigate climate change by renewable energy generation through RECs (see Chapter 2)

Handling RECs on the blockchain entails a few advantages. First, solar energy production can be tracked on the blockchain and as a consequence RECs can be created accordingly through tokenizing generated energy. This process makes REC creation verifiable and transparent. Second, trading RECs on the blockchain untwisted the centralised and complex REC trading system as mentioned above. Technically every market participant who is registered on a blockchain-based REC platform can issue, trade and buy RECs. Thus, the key blockchain characteristics here are disintermediation, immutability, transparency, trustlessness and tokenization ability.

## 5.2.3 Transparency regarding procured energy mix

### *The business model*

While RECs are certificates of renewable energy produced, they do not actually guarantee that the consumer receives green power at home. Once green power is injected into the grid, it 'mixes' with electricity generated in fossil-fuel power plants and becomes grey power[8]. This aspect of the current energy market has not been addressed yet. GrünStromJeton (literally meaning 'green power token') offers a possible solution by estimating the share of green power in the total energy mix. The project targets prosumers and consumers but could also be deployed by retailers and utility companies to inform their customers. Currently, the system is applied on a regional scale, although it has potential to be globally applicable, if the necessary information about the energy mix is retrievable on a local level. The value

[8] The term is literally translated from the German term 'Graustrom', which refers to power that is of unknown origin and is usually used as the opposite of green power.

proposition for the target customers is increased transparency regarding the procured energy mix. The value is delivered through tokenisation. The consumption data can either be registered by the meter operator using automated meter-reading or manually, if two readings are available. Then, either in real-time or retroactively for a given time period, the actual share and amount of green power is calculated based on a green-power index, the zip code and the meter data. For each kWh of green power, a token is issued. The tokens, called GrünStromJetons, are issued using the Ethereum blockchain. The project runs open source and everybody can freely access the information.

### *Implications for the electricity market*

The described transparency system can illustrate the gap between the electricity paid for or the goal of using 100% electricity from renewable energies, and the actual energy mix which reflects the standard load curve. First, this can improve the accountability of utility companies and retailers promising environmentally friendly energy. Second, conscious consumers can adapt their electricity consumption in light of the real-time energy mix, running energy-intensive appliances during a time of green-power peak production.

The main characteristic this model takes advantage of is its distributed and transparent manner. Moreover, the system tokenizes the received energy mix. However, in contrast to the above mentioned REC model, there is no such market yet for the created tokens. Therefore, this transparency system is rather a transparency and accountability tool to track the advances in energy transition strategies on a regional or local level.

## 5.2.4 Crowdsale platform

### *The business model*

This type of business model is similar to the online crowdfunding platforms Indiegogo or Kickstarter but is focused on solar PV projects. The target customers are private investors as well as property owners who have suitable land or roof area for solar PV. The potential network size or outreach for this type of business model is the global scale, meaning that an investor in Europe can invest in a project in Australia. Investors are offered rent in exchange for investing, while property owners benefit from the potential sale of surplus electricity and lower electricity costs when consuming the generated energy themselves. The value chain is built on a platform on which property owners can suggest their solar PV projects. Interested investors can then fund the projects, which are developed once sufficient funds are collected.

Investors have shared ownership of the solar PV and get a continuous rent on the sale of surplus energy production, while property owners lease the solar PV from the investors. The companies involved provide a platform to connect the parties and act as a service provider for marketing, the arrangement of leasing agreements or power purchasing agreements, and profit distribution. The shared ownership is arranged using tokenisation through the Ethereum blockchain. Because of this, the crowdfunding process is oftentimes called crowdsale in this context; it is a specific type of crowdfunding in which tokens are issued. People holding tokens get either a share and/or the right to pay for services as part of the platform. In one instance, however, the platform runs on a public blockchain on which payments can be made using bitcoin or a local currency. Even so, cross-border investment transactions are enabled on both the Ethereum-based and public platforms. Revenue sources differ between the three cases studied. One project's software is free and open source, while another case charges a transaction fee and the third one collects a commission fee on successfully funded solar PV projects and collects an annuity.

### *Implications for the electricity market*

Crowdsale platforms decentralise financing processes within the energy market. This has four positive effects on the energy market and society. First, crowdsales make private solar PV installations more accessible to the public. Households and small commercial enterprises, who might not afford it otherwise, can profit from a lower financial barrier to solar PV. In particular, the crowdsale model helps in areas with little financing mechanisms and infrastructure in place such as in sub-Saharan Africa, which is a special focus of one of the analysed case studies (The Sun Exchange). Second, property owners are energy consumers in this arrangement and can profit from lower electricity costs. Third, individuals can invest in RES projects outside of the regular project-finance processes. Taking the three effects into account, all are relatable to the organised resource sharing trend elaborated in section 3.1 on sharing economy. Essentially, individuals, communities and enterprises make their potential solar PV area available to the general public and share the financial benefits thereof. Fourth, crowdsale platforms can boost the installation of solar PV and thereby advance the attainment of climate-change-related policies and decarbonisation targets. Hence, the crowdsale platform fosters decentralisation, decarbonisation and electrification. However, a major drawback of the analysed case studies and the underlying business model is that they don't address the technological challenge of the shift in load curve. If anything, the focus on the financial model that boosts small-scale RES further contributes to the over-generation during the day. The crowdsale business model benefits from blockchain through connecting investors and recipients in a trustless network. Centrally organised financial mechanisms and project funding in the area of RES are disintermediated. Based on predefined smart contracts, the rent payments are automated and reflect the real-time energy generation on the installed solar PVs.

### 5.2.5 OTC trading platform

#### *The business model*

The OTC trading platform is a distributed marketplace for OTC trading of wholesale energy. The target customers are energy producers, utility companies and retailers within the European power and gas market. The value proposition is to reduce the transaction costs for trading large volumes by making operational processes more efficient. The value chain is based on a platform which connects the trading desks of all parties. Through the platform, the market participants can initiate and physically settle power and gas trades. The trades are anonymous and only the involved parties know each other. The platform is set up on a Tendermint[9] blockchain. The plan is to integrate an energy-trading and risk-management system as well. The platform is delivered by a software company and over 30 companies have already joined the proof-of-concept platform. Among the partners are some of the biggest European energy companies: Enel, E.ON, Iberdrola, RWE, Statkraft, Statoil, Total and Vattenfall (PONTON, 2017a). Because the project is a cross-industry collaboration with the software company, there is no public information available regarding the software company's revenue streams.

#### *Implications for the electricity market*

Blockchain enables that all market participants can connect and share information with each other without an intermediary or broker. Here, the OTC-trading platform eliminates the broker company. The participating partners using the platform can expect to reduce their transaction costs and to potentially pass on the benefits to consumers. As a consequence of lower transaction costs, the OTC market could potentially be expanded to participants with smaller trading volumes. Following the decentralisation trend of the energy market (see

[9] This is a blockchain software similar to Ethereum.

Chapter 2), the OTC-trading platform takes the discussion further to decentralise energy trading processes as well.

### 5.2.6 Flexibility-trading platform

#### *The business model*

Two cases can be categorised as flexibility-trading platforms. Of these, one integrates flexible capacities such as household battery storage or EVs, and the other addresses demand-side responses. The target customer groups are prosumers, consumers and system operators. So far, the projects have been implemented or are in development on a regional level. The value proposition is, on the one hand, to offer remuneration for adjusting one's energy consumption. On the other hand, the platforms promise to lower electricity costs or to shorten the pay-back period for household storage systems/EVs in exchange for renting the household storage capacity to the system operator. The value chain is rooted in a (private) blockchain-based platform that connects all the storage units and smart home appliances. Their capacity and availability is recorded on the blockchain. Based on this, there are two options for controlling devices. First, battery systems can store electricity when demand is low and feed electricity back into the grid during peak consumption periods. Second, home appliances can shift their energy consumption between peak and off-peak hours when needed. In this way, the network of storage and home devices enables grid stabilisation and balancing. As one project is a collaboration between a TSO and a storage manufacturer, there is no information regarding the revenue streams, as it is in the interest of and the responsibility of the TSO to balance the grid reliably. The second case concerns a start-up that received funding from the UK government to develop a demand-side-response trading platform. A potential revenue model for the start-up is to offer the solution as a platform-as-service to system operators.

#### *Implications for the electricity market*

The cases discussed integrate household devices and storage systems into the flexibility market by connecting them into a network which can be activated when needed. Again, this is enabled by the blockchain's core characteristics as information can be updated and shared near real time. While the main beneficiary of the setup is technically the system operator, it also offers financial value to consumers. Overall, the flexibility-trading platform provides three main solutions to the electricity market. First, connecting more and more devices and storage units to the grid with the aim of integrating them into a flexibility market expands the overall available flexibility capacity. With an increasing share of intermittent renewable-energy generation, the higher capacity value supports system operators in stabilising and balancing demand and supply. Second, the increased capacity increases together with the liquidity of the flexibility market, making it easier to schedule flexibility sources at short notice. Especially when conventional power plants are used for re-dispatching to stabilise the grid, the power plants cannot be shut down instantly. Here, the increase in residential demand-side flexibility shortens scheduling periods. Third, the platforms can lower the costs associated with flexibility measurements, considering that re-dispatch interventions are very costly (Appunn, 2016; Coyne, 2017; Ecofys, 2014). Thus, expanding the flexibility market to households enabled by blockchain-connected devices provides a solution to shifting load curves due to increasing over-generation by RES.

### 5.2.7 P2P energy-trading platform

P2P energy-trading platforms are at the moment the most common blockchain-based applications within the energy market. The current analysis has shown that half of 22 cases address the local energy-trading market between prosumers and consumers.

#### *The business model*

While the core concept of the P2P energy-trading platform is shared by all the cases using this business model, it manifests itself in four different forms. First, there are platforms which are currently operating (or in proof-of-concept) on a local level and target producers, prosumers and consumers. Second, some projects predominantly aim to offer the P2P trading marketplace as a platform-as-a-service to utility companies and retailers. Third, a few cases intend to target prosumers and consumers and to implement their platform on a global scale, in some cases using hybrid blockchain solutions on a local and global level. Fourth, some cases incorporate two models: addressing producers, consumers and prosumers with a local P2P platform as well as utility companies and retailers with their platform-as-a-service. The value propositions are the sale of surplus electricity for prosumers; higher remuneration for renewable energy producers; lower electricity prices and increased transparency as well as flexibility over the preferred energy mix for consumers; and lower administrative costs for utility companies and retailers. The value chain unfolds on an energy-trading platform, which is implemented using an Ethereum blockchain in almost all cases. In addition, most projects tokenise the data. As the platforms operate on top of the grid but still rely on infrastructure, compensation for transmission and distribution is collected by the platforms and provided to the system operator. Regarding the software, artificial intelligence enables energy-management services and forecasting supply and demand. Two projects deliver smart meters in addition to software. At a later stage, some projects intend to integrate other features such as storage-capacity trading. On the financing side, it can be seen that all three purely local P2P energy platforms are backed by or emerged out of corporate partnerships and projects, while the majority has launched or already successfully closed initial coin offerings. The standard revenue source is transaction fees. The platform-as-a-service solutions are offered through licensing agreements.

### *Implications for the electricity market*

As with the mentioned OTC and flexibility-trading platform models, prosumers and consumers are connected to trade energy directly with each other. This business model has four implications for the electricity market.

First, the business model makes use of the blockchain technology to automate processes and skip intermediaries, for example, by triggering payments and energy transactions through smart contracts. Automation and disintermediation reduce administrative costs, which lowers the barrier for communities to implement such P2P energy-trading systems. Likewise, if utility companies implement a platform-as-a-service or their own platform, they can also benefit from lower operational costs. In both cases, consumers can profit from lower electricity costs, while producers/prosumers can obtain a higher remuneration.

Second, the P2P energy-trading platform localises the energy market and consequently reduces the burden on the transmission grid, which is especially strained by large-scale, intermittent RES. This is particularly noticeable in Germany. The large wind power production but high-energy consumption in the South creates a bottleneck problem on the transmission grid. Local energy markets with integrated balancing mechanisms could therefore increase the overall grid efficiency.

Third, prosumers and consumers are empowered by participation and can experience a higher sense of belonging to a community through the sharing economy trend. This was not possible in the former top-down electricity market design. Consumers can choose between supporting their immediate neighbouring prosumers and procuring power from the utility company or retailer. By doing this, they can independently set their price preferences or negotiate the prices on the P2P platform. Within the value proposition, this builds on the analysed criteria of flexibility and transparency.

The key blockchain characteristics that facilitate the business model of P2P energy-trading platforms are being able to build a trustless network with a distributed record and the use of smart contracts. Smart contracts execute price preferences, tokenise the energy produced and transact energy trades and payments.

## 5.3 Discussion

Seven blockchain-based business model archetypes in the electricity market have been identified: retailers, REC-incentive scheme, proof-of-green-power procurement, OTC-trading platforms, flexibility-trading platforms, crowd-sale/funding platforms and P2P energy-trading platforms. The assessment of the business models revealed the implications for the electricity market. The retailer, the REC-incentive scheme, and the OTC-trading platform are not inherently transformative but, to a certain extent, they innovate on different business model dimensions. They utilise blockchain characteristics to disintermediate in the value chain, redesigning and automating processes to increase their efficiency and thus cut administrative costs. In addition, the blockchain-based REC system is superior to the current REC system by making the REC issuing process verifiable and transparent. The platforms that operate in the flexibility and P2P energy-trading markets present new means of addressing the challenges and implementing the solutions that have been discussed in research and practice in terms of the electricity market. Moreover, they build on prosumers and further promote residential and small-scale commercial solar PV deployment. Blockchain-based crowd-sale/funding and OTC-trading platforms have further advanced the decentralisation of the electricity market by minimising the entry barrier into their field of application. The former has minimised individuals' need for solar PV investments and has allowed a new target customer (private investors) to participate in the electricity market. The latter has reduced trading transaction costs through disintermediation, thus disburdening smaller traders. Last, proof-of-green-power procurement is a novel transparency and accountability tool to reveal the actual share of green power in energy consumption, although there is no market for this data yet.

From a wider perspective, these blockchain-based business models have modified and added new characteristics to the four business model dimensions. First, compared to the conventional electricity market, the target customer group has been extended by two customers: Prosumers and private investors. Second, in terms of the value proposition, in addition to generating revenue and cutting costs for the customers, these business models have offered the attributes of transparency and flexibility. Third, the value chain processes have been dominated by smart contracts and tokenisation, both of which go hand in hand with blockchain technology. Fourth, the revenue streams have not challenged current market practices, although it should be noted that a majority of case studies in the prosumer/consumer oriented business models (retail and P2P energy-trading platforms) charge transaction fees while only one case uses a subscription model. Hereby, the former cases are not intrinsically motivated to encourage energy-efficient behaviours by consumers, whereas in the case of a subscription model, the company's profit is not correlated to consumers' energy consumption.

Considering all of the above, the business models have addressed the energy market trends and challenges elaborated in Chapter 2, taking advantage of the socioeconomic and technological developments outlined in Chapter 3. They have promoted renewable energies through additional remuneration and electricity cost cutting; however, this benefit can be overshadowed if a business model's sole purpose is to one-sidedly promote RES, such as for the crowd-sale/funding platform. The good news is that through the integration of storage and the control of home devices, some P2P energy-trading platforms and flexibility-trading platforms offer an attractive solution to accelerate demand response and demand-side management. This way, the negative consequence of the RES, i.e. the shift in the load curve, can be overcome. Likewise, the increasing rate of electrification can potentially be absorbed by the higher degree of the RES. All of the business models have taken advantage of and relied on digitalisation. On the one hand, the case studies have highlighted superior user interfaces than conventional energy providers and services. On the other hand, some processes have been enabled by digitalisation in the first place, such as tokenisation and the automation of energy and payment settlements.

In sum, blockchain-based business models promote green energy, increase efficiency and lower energy costs. Hence, the three characteristics that are rooted in the business model dimensions of value proposition, value chain and value capture allow organisations to add value to customers and to lower costs at the company end.

# 6. Considerations for a P2P energy-trading platform

Building on the identified retail and P2P business models in Chapter 5, this chapter takes a closer look on P2P energy-trading platforms and evaluates what considerations have to be made. As the basis for this analysis are energy consumption and generation data from a smart grid pilot project in Norway, a brief overview on prosumer regulation will be given.

## 6.1 Regulation in Norway: Plus customer scheme

In 2010, the Norwegian water resources and energy directorate (NVE) introduced regulations regarding local energy production and prosumers, called plus customers in Norway[10]. The regulations concerns small-scale electricity producers who mainly generate electricity for self-consumption, except for some high-generating hours during the day. Prosumers who are net consumers on a yearly basis are allowed to feed their surplus electricity into the grid without the need for a concession and a requirement for a balancing agreement with Statnett. The local grid company can purchase the surplus electricity on a voluntary basis. In this case, the plus customer is compensated the hourly spot price but needs to pay a variable grid fee based on marginal losses. The fee, however, could result in additional compensation for plus customers because distributed generation can reduce marginal grid losses (Holm, 2015; NVE, 2017). The initial regulations were revised by the NVE in 2014–2015 and came into force in 2017. The revisions now make it mandatory for energy suppliers to buy surplus electricity from plus customers, with a maximum injection into the grid of 100 kW at any time. In addition, the plus customers can receive RECs and are not required to pay an additional grid charge anymore (Bellini, 2017; International Energy Agency, 2017a). Overall, local P2P energy-trading is so far not regulated as part of this plus customer scheme.

Moreover, the TSO Statnett was commissioned by the NVE to establish the power-system data repository Elhub. Elhub will register every customers' consumption and generation data. A prerequisite will be a nation-wide smart-meter roll-out by 2019 (International Energy

[10] These are called plusskunder in Norwegian.

Agency, 2017a). These meters will register electricity in- and outflows every 15 minutes and report hourly (Van Der Schoor & Scholtens, 2015).

## 6.2 Methodology and data used

The analysis and comparison are conducted in XY steps. First, the energy consumption and production data are analysed in the current market setting of Hvaler. The electricity costs for the consumers as well as the revenue for surplus energy to prosumers is calculated. For this purpose, the regular contracts of these customers are taken into account. Hence, electricity prices and data from each respective energy supplier and grid operator are considered. Second, the same electricity consumption data serve as a basis for analysing the P2P business models and projects. The projects' customer costs and fees are taken into account. The scope is limited to projects for which this information is available or for which it is possible to make assumptions based on information given about the business model. Third, the initial market situation in Hvaler is compared to the outcome of the P2P setting.

The analysis is based on anonymized electricity consumption and generation data for 17 pure consumers and 5 prosumers in Hvaler, Norway. The data were provided by Norgesnett AS, the responsible DSO in the municipality Hvaler. The consumer and prosumer are part of the EMPOWER smart grid pilot[11] and agree to have their data used for academic purposes (S. Ø. Ottesen, personal communication, February 9, 2017). Hourly net metered electricity consumption and generation for each consumer and prosumer is given in kWh for the period 01.01.2015-31.12.2016. The prosumers installed the solar PV during the summer of 2015. To simplify the analysis, it is limited to a one-year period from January 2016 to December 2016. To determine the consumers' and prosumers' electricity costs additional data was used. First, the hourly day ahead price from NordPool Spot were downloaded (Nord Pool AS, 2017). The data is also the basis for the variable electricity price component with the supplier. Second, specific elements of the supplier contract and the grid contract are elaborated in chapter 6.3.1. Third, for the P2P energy trading analysis elements of the business model in chapter 5.2.7 are used.

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[11] EMPOWER is an abbreviation for local electricity retail markets for prosumer smart grid power services. It is a n EU-funded, collaborative research project to investigate advantages and opportunities of innovative business models in local electricity markets (EMPOWER H2020, n.d.).

## 6.3 Analysis

### 6.3.1 EMPOWER smart grid pilot in Hvaler

*Contract specifications*

There are a total of $i$ = 22 energy consumers (pure consumers and prosumers), thereof are $k$ = 5 energy generating prosumers and $j$ = 17 pure consumers. The data is given in hourly time slots t ∈ T over the year 2016. As the energy costs will be calculated on a monthly basis, the demand and generation will be aggregated for each month $m$. Each energy consumer consumes energy demand $d_{it}$ in kWh and each prosumer is generating $g_{kt}$ in kWh, respectively $d_{im}$ and $g_{km}$. The consumers and prosumers hold an energy contract with the retailer Smart Energi and a grid contract with the DSO Norgesnett (Norgesnett, 2017). The energy contract consists of two components. First, the energy consumers pay a fixed fee $f_e$ = 39 NOK/month. Second, they pay a usage based fee which is the monthly average day-ahead price from NordPool Spot $c_{em}$ in NOK/kWh[12]. The grid contract consists of three components. First, there is a fixed grid fee $f_g$ = 625 NOK/year. Second, an energy based fee is charged depending on the season. In the 'summer' months May to October the fee is $c_s$ = 0.2603 NOK/kWh; in the 'winter' months November to April the fee is $c_w$ = 0.2790 NOK/kWh. Third, an additional demand charge is applied. For each month, the average of three highest hourly consumptions $D_x$ (for $x$ = 1,2,3) from three different days is taken and multiplied with the demand charge $c_d$ = 61.25 NOK/kW. Then the monthly energy cost (here May to October) for each energy consumer is given by:

$$f_e + c_{em} * d_{im} + \frac{f_g}{12} + c_s * d_{im} + c_d \frac{D_1 + D_2 + D_3}{3} \qquad (1)$$

so, 39 NOK + $c_{em} * d_{im}$ + 52 NOK + 0.2603 NOK/kWh * $d_{im}$ + 61.25 NOK/kW$\frac{D_1 + D_2 + D_3}{3}$.

The plus customers, here prosumers, are compensated by Smart Energi for their surplus energy generation $g_{kt}$. The fixed compensation price is $p_c$ = 0.8 NOK/kWh (Smart Energi, n.d.). In addition, the prosumers are compensated by Norgesnett at $p_g$ = 0.02 NOK/kWh (S. Ø. Ottesen, personal communication, November 29, 2017). Then the prosumers' monthly compensation for their surplus energy generation is given by:

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[12] Data was originally downloaded in NOK/MWh and converted to NOK/kWh by the author.

$$p_c * g_{km} + p_g * g_{km} \qquad (2)$$

so, 0.82 NOK/kWh * $g_{km}$. Essentially, the net electricity cost of the prosumers is then energy costs (1) minus the surplus energy compensation (2), (1)-(2).

### *Overview of energy consumption and generation*

In the following, energy data is presented in net consumption and net generation as it was gathered this way. Net consumption in the case of consumer *j* means this data corresponds to gross consumption. However, in the case of prosumer *k*, net consumption equals total consumption minus generation. Reversely, net generation of prosumer *k* is total generation minus consumption.

Below, the monthly average (net) consumption across consumers and prosumers is shown. Two things can be seen. First, energy consumption is significantly lower during the summer months than during colder winter months. Second, prosumers' net consumption is throughout the year lower than consumers' consumption. While the sample size of 5 prosumers versus 17 consumers is relatively small, this is most probably attributable to solar power generation on the prosumers end. On average the total net consumption of consumers amounts to 25'658 kWh in 2016. The average total net consumption of prosumers amounts to 20'652 kWh.

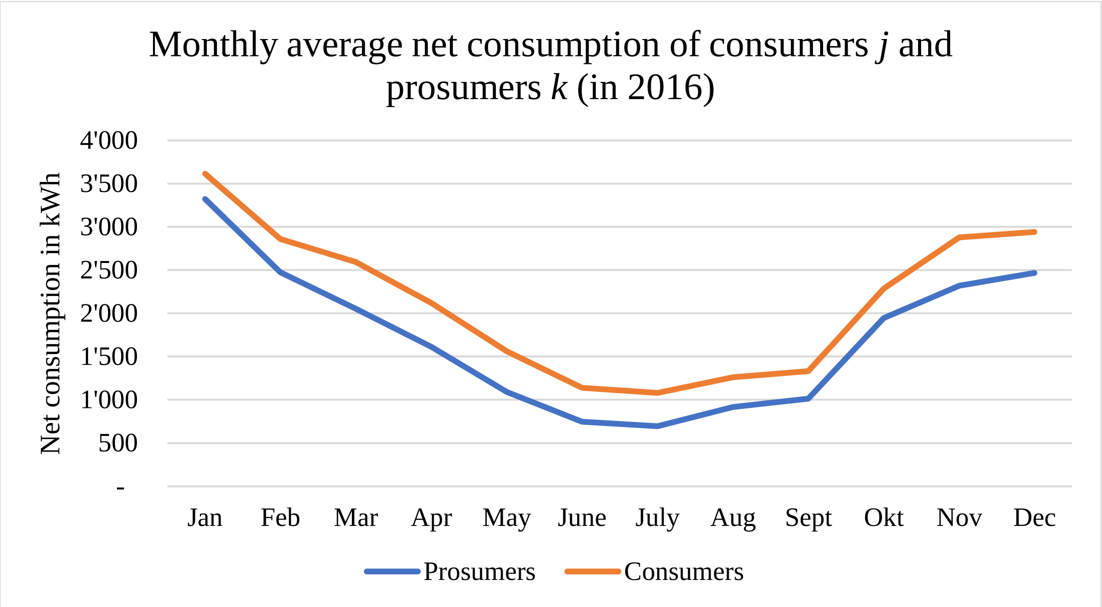


*Figure 4: Monthly average net consumption of consumers j and prosumers k (in 2016)*

Below, monthly net generation by prosumers is shown. In January, November and December almost none net generation occurred[13], while it is largest in June and July. The net generation represents a bell-shaped curve reflecting the daylight hours in Norway. The amounts are the basis for the compensation for surplus energy generation.

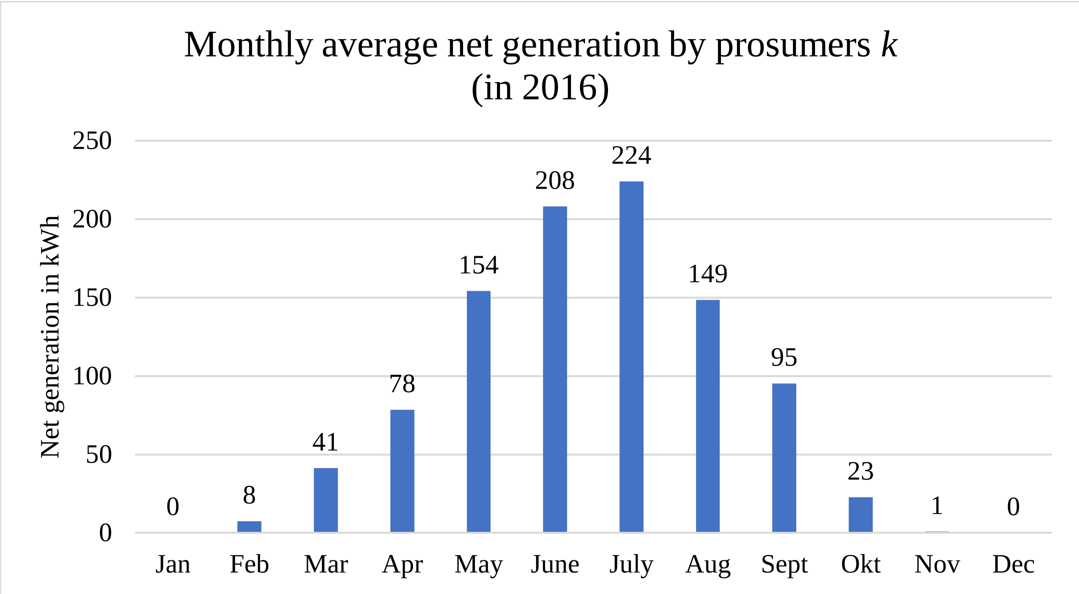


*Figure 5: Monthly average net generation by prosumers k*

Comparing net generation with net consumption of prosumers, it can be seen that for instance in July the average surplus energy generation is 224 kWh, while average net consumption is 695 kWh. Even under the assumption that the surplus energy could be stored, net generation isn't sufficient to cover for the remaining net consumption of prosumers. Hence, the installed capacity wouldn't allow the prosumers to be self-sufficient. Having this in mind, surplus energy generation would be by far too little to even cover for consumers' energy consumption.

### *Electricity costs*

Below, the monthly average electricity costs for consumers and prosumers are depicted. It includes the compensation for surplus energy generation by Smart Energi and Norgesnett. It can be seen that the cost curves generally mirror net consumption (figure 6). The total average electricity costs for consumers in 2016 are kr.20'473. For prosumers, costs for net consumption equal on average kr.16'857. The compensation for surplus energy generation

[13] 0.14 kWh in January, 0.814 kWh in November, and 0.062 kWh in December.

amounts to kr.805. Hence, prosumers pay on average kr.16'042 or 22% less than consumers do.

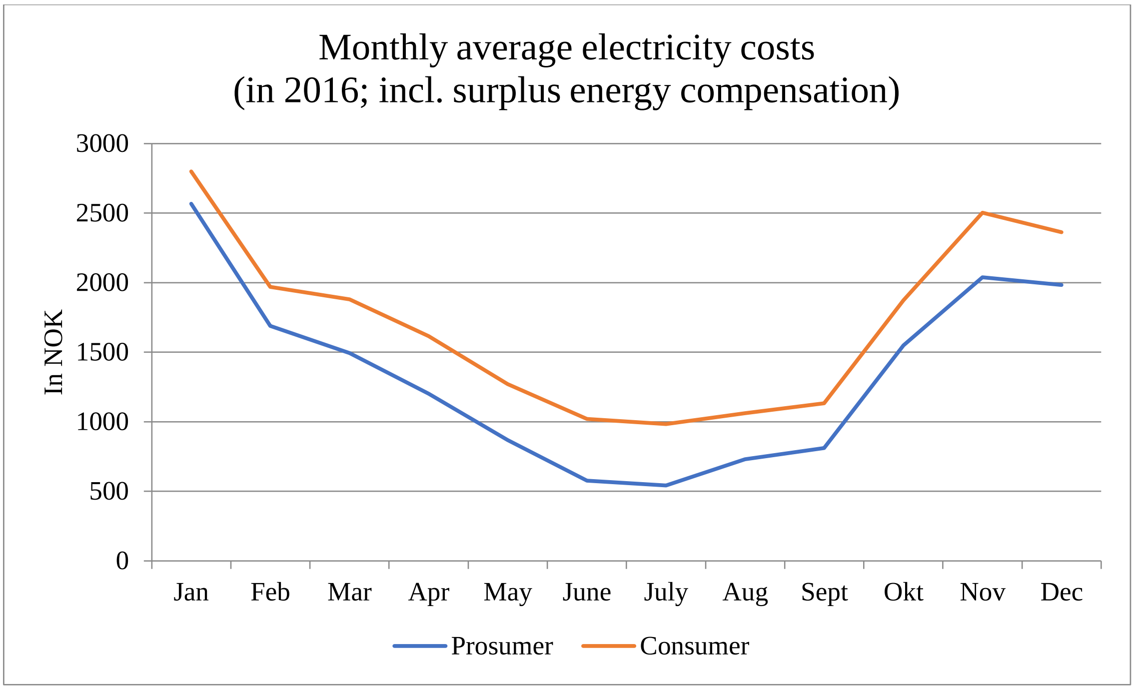


*Figure 6: Monthly average electricity costs (in 2016)*

In comparing consumers' yearly electricity costs against the prosumers' electricity costs, it can be concluded that this difference is by tendency due to prosumers' net consumption which already takes into account generation. Meaning, while surplus energy compensation would only reduce prosumers' net consumption costs by around 5%, it could be implied that the generated energy which is consumed by the prosumer itself, explains to a greater extend the difference in (net) consumption costs of consumers and prosumers. Unfortunately, this hypothesis can only be examined with gross consumption and generation data of prosumers. Moreover, it could be that prosumer households are in general more energy efficient than the average consumer household. The sample size is not representative enough to offer a final conclusion on this matter.

### *Evaluation*

Smart Energi can be mapped against a blockchain-based retailer, Drift, which was analysed in chapter 5.2 (see Appendix C and D for more information on Drift). Drift customers' total electricity costs contain an energy and a grid component. The energy component includes likewise a fixed and a variable consumption-based fee. The latter is the wholesale price which Drift passes on. The grid component is the transmission and distribution charge to the DSO. Hence, both Smart Energi and Drift are

### 6.3.2 P2P energy trading

If Smart Energi implemented a P2P energy-trading platform as part of the EMPOWER smart grid pilot in Hvaler, the retailer would need to consider several things. First question that should be answered is how Smart Energi would set up the P2P energy market. Mengelkamp, Gärttner et al. (2017) developed a schematic overview of blockchain-based microgrid energy markets. They derived seven components based on Block et al. (2008) and Ilic et al. (2012) relevant to an efficient operation of such markets: microgrid setup, grid connection, information system, market mechanism, pricing mechanism, and energy management trading system (EMTS). In the following, the components will be addressed with regard to the current market setup with Smart Energi.

First, Mengelkamp, Gärttner et al. (2017) state that 'a clear objective, the definition of market participants, and the form of energy traded must be defined' (p. 4). Here, the market participants are consumers, prosumers and Smart Energi. Smart energy is the retailer respectively the supplier of previous net consumption. Prosumers are delivering surplus solar energy which serves as a basis for energy trading. The market boundary is for this purpose the EMPOWER smart grid community, or in this case a total of 22 consumers (including prosumers). The existing smart grid can be used.

Second, a grid connection between the microgrid and superior grid must exist to balance energy generation and demand local P2P energy trading is so far not regulated as part of this plus customer scheme. It is assumed that this applies to the smart grid in Hvaler as the majority of the energy couldn't be met with prosumers' net generation (see above in chapter 6.3.1). Against this background a decoupling and island-mode operation is not possible because the installed solar PV capacity is too small. So, Smart Energi is required to supply a significant portion of the demanded energy.

Third, '[an] information system is needed to connect all market participants, provide the market platform, provide market access, and monitor the market operations' (Mengelkamp, Gärttner et al., 2017, p. 5). Here, it is assumed that Smart Energi and Norgesnett have currently the adequate information system to monitor consumption and generation. However, considering the intention of a blockchain-based platform, the information system would need to be revised. Particularly, equal access for all prosumer and consumer has to be ensured. Hereby, Mengelkamp, Gärttner et al. (2017) remark:

> A secure connection from the market participants' smart meters, which measure and monitor energy generation and demand, to the blockchain is necessary. Secure smart meters can then write the required energy data directly into the corresponding blockchain accounts. (p. 5)

Hence, adequate smart meters have to be provided. Regarding the blockchain, it would be most applicable to implement a private blockchain in the smart grid pilot. Meaning, the verification mechanism in the P2P platform depends on the microgrid setup above. So, within the smart grid pilot, identities are still needed to be verified to acquire access to the platform in order to prevent fraudulent use of personal information.

Fourth, a market mechanism, which is implemented by the blockchain, has to be designed. It encompasses allocation rules and a bidding format (Mengelkamp, Gärttner et al., 2017). Pilz & Al-Fagih (2017) discuss game theory to evaluate the behaviour and preferences of different participants in energy trading. Hereby, the frequency and chronology of play, and the information awareness and knowledge of players needs to be evaluated. In the setting of local energy markets, Mengelkamp et al. propose a 'closed double auction market with price-time precedence and discrete market closing times that results in a single clearing price per trading period *t*'(Mengelkamp, Notheisen, Beer, Dauer, & Weinhardt, 2017, p. 4). They argue that while auctions are approapriate for intraday trading, over-the-counter trades may be more suitable in P2P negotiations. In the case of EMPOWER, consumer and prosumer would need to decide on their price limits at which they would buy and sell electricity.

Fifth, a pricing mechanism, which is implemented through the market mechanism, should serve to efficiently allocate energy supply and demand (Mengelkamp, Gärttner et al., 2017). According to Mengelkamp, Gärttner et al. (2017), prices should also signal energy scarcity or surplus. This way, the consumers are incentivized to adjust their energy consumption. Ideally, during high solar energy generation periods, electricity prices are low to encourage demand, and vice versa. Also, Mengelkamp, Gärttner et al. (2017) note that 'Economically speaking, local markets are beneficial to their participants as long as the average energy price is lower than the external grid price' (p. 6). Consequently, in their simulation of a blockchain-based local energy market, Mengelkamp et al. set the lower local price limit to the German feed-in tariff (ca. 0,12 EUR/kWh) and the upper local price limit to the German electricity price (in the simulation set to ca. 0,29 EUR/kWh). Therefore, electricity price for grid transactions is higher than of the local energy market, here the P2P energy-trading platform, to maximize local transactions and promote the community's self-consumption. In the case of Hvaler, the upper price limit would equal the Elspot price plus the variable grid fee[14]. The average Elspot price in 2016 is 0.24 NOK/kWh. The average grid variable fee is 0.27 NOK/kWh. Hence, the upper price would amount to 0.51 NOK/kWh. Basically, the compensation rate by Smart Energi and Norgesnett equals the lower price limit of the German feed-in-tariff by Mengelkamp et al. If Smart Energi and Norgesnett were still to compensate prosumers when a P2P trade couldn't be settled, the previous compensation rate of 0.82 NOK/kWh would apply. Now, the price limits are 0.82 NOK/kWh and 0.51 kWh. However, in this setting the prosumer would be encouraged to be compensated by Smart Energi and Norgesnett, instead of offering their surplus energy to trade with consumer. To follow Mengelkamp's pricing principles, Smart Energi would have to either adapt the compensation rate of 0.80 NOK/kWh, or to abandon it altogether. Moreover, the fact that the compensation rate is higher than the electricity price (here incl. energy-based grid fee: 0.51 NOK/kWh) is a major flaw in the current pricing mechanism of Smart Energi. It sets the wrong incentives in energy consumption, and actually reverses demand response and demand-side management considerations.

Sixth, an EMTS is needed to 'automatically secure the energy supply for a market participant while implementing a specific bidding strategy' (Mengelkamp, Gärttner et al., 2017, p. 6). Its purpose is to forecast energy consumption and generation, and to facilitate energy transactions following the bidding outcomes on the P2P platform. In the case of the EMPOWER smart grid pilot, it is assumed that a comparable system is already in place for forecasting. Hence, it should still be tested for its suitability in a blockchain-based system, and for incorporating bidding strategies.

Seventh, all of the above elaborated components need to be considered in the light of regulation regarding local energy markets and P2P energy trading (Mengelkamp, Gärttner et al., 2017). As stated in chapter 6.1 on regulation in Norway regarding prosumers, local P2P

[14] For the purpose of these deliberations, the demand charge as well the fixed contract fees with Smart Energi and Norgesnett were disregarded.

energy trading is till now not regulated as part of the revised plus customer scheme which came into force in 2017. This means that Smart Energi and Norgesnett wouldn’t be able to implement a blockchain-based P2P energy-trading platform given the regulatory framework for prosumers in Norway.

# 7. Conclusion

## 7.1 Findings and contribution to theory and practice

Regarding the research gap identified in terms of blockchain-based business models within the electricity market, Chapter 1.2 raised the clarifying questions and research questions for this paper. First, the clarifying questions concerning the leading trends towards a decentralised electricity system were answered. Chapter 2 introduced four central market trends: Climate change, decentralisation, electrification, and digitalisation. Structural challenges to the electricity system, in particular technological and economic ones, were subsequently outlined. Outside of the electricity system, general socioeconomic and technological developments were introduced in Chapter 3; specifically, the concept of sharing economy proved to be relevant in this context. In addition, blockchain technology was largely explained in order to lay down the foundation for subsequent research and analysis. Second, to answer the research questions regarding blockchain-based business models, a literature review of business model definitions and dimensions was conducted in Chapter 4. In a first step, it was concluded that a four-dimensional analysis grid is the most applicable framework to analyse the identified case studies. The second step involved a detailed extraction of categories and their characteristics for each of the four business model dimensions derived from a first review of the case studies. These categories helped to specify the business model archetypes of the case studies at hand. As a result of this paper, seven blockchain-based business models in the electricity market were defined. The implications on the electricity market were analysed and concluded in Chapter 5. Third, a preliminary analysis and discussion on P2P energy-trading platforms was made on the basis of the current market setup of the EMPOWER smart grid pilot in Hvaler.

In sum, the paper has added value to research and practice in three ways. First, it has facilitated discussions about the blockchain and its practical use in the electricity market by identifying blockchain-based business models. Second, it has clarified the implications for the electricity market when these business models are implemented. Third, it has casts light on what needs to be considered when implementing a blockchain-based P2P energy-trading platform.

While industry-specific media coverage has noticed the growing interest in blockchain technologies and their application to the energy sector, it has mostly focussed on the specific pilot launch events of start-ups and corporate ventures. This paper has created a greater transparency and overview of the various case studies in this field. It has presented the blockchain technology's advantages and areas of application and the status quo of business practices. It has become clear that blockchain-based business models are largely still in the pilot phase and a large-scale implementation is not yet within reach. Nevertheless, the implications elaborated on the electricity market provide an insight into a promising future of renewable and distributed energy markets utilising blockchain technology.

## 7.2 Limitations and areas for future research

The blockchain technology only exists since 8 years. Consequently, research in the field of blockchain is still in the early stages and faces a series of limitations. This also applies to this thesis. The analysis of blockchain-based business models is limited by three factors: the restricted availability of information, the limited scope of the analysis, and the fast development of the industry. First, the analysed case studies did not always offer full information on all aspects. As the application of blockchain technology in the electricity market is not established yet, many companies are either small start-ups that only publish very little public information because of their limited size or larger enterprises that do disclose more information to secure their intellectual property. Second, to ensure a focused analysis this thesis only analysed case studies in the electricity market or along the electricity value chain. Hence, the application of blockchain to mobility, electric vehicles, or other energy-related topics was excluded although it could have an impact on the overall electricity market as well. Third, the landscape of blockchain applications in the electricity market is changing very quickly. New use cases are not only driven by the technological advancement, but also the overall development of an ecosystem including start-ups, established corporations, investors, facilitators and researchers. Therefore, this thesis can only present a snapshot of the current business model landscape.

The analysis of the EMPOWER smart grid pilot in Hvaler is limited by three factors. First, the size and the composition of the sample limits the transferability of the analysis to the overall population as the sample consists of only 22 consumers, 5 of them being prosumers. Second, the representativeness of the data for the overall population is not ensured. This might not only relate to personal preferences of the consumers, but also systemic biases through the high compensation of 0.82 NOK per kWh for prosumers; with the market price being considerably lower, prosumers are incentivized to shift their consumption pattern to maximize their selling potential on sunny days. Third, the study of trading is limited by low installed capacity. Often the produced electricity by PV is entirely consumed by the prosumer and even in times of trading additional energy always need to be sourced from the grid.

This thesis has established a foundation for future research by analysing blockchain-based business models and deriving their impact on the electricity market. In the area of the business models, future research should especially focus on regulations and scalability. First, the regulatory environment is a key aspect in the blockchain technology. With the continuous growth of the technology, regulatory frameworks are expected to catch up and to try to provide centralized guidelines. As decentralization without regulatory intervention besides the consensus mechanism is a key core pillar of the blockchain functionality, increased regulation needs to be further explored by future research to understand how it influences the configuration of the business models and how it changes their respective chances of success. Second, future research should consider the scalability of the identified business models. This is important as the blockchain technology per-se allows scalability, but depending on the business model additional constraints might hinder it. For examples, depending on the blockchain and the consensus mechansism that are used the mining process can be highly energy intensive, thereby creating financial constraints for increasing volume. Also, some business models depend on existing technology such as smart meters to be able to leverage their blockchain advantages. These models are dependent on the adoption of smart meters and hence limited in their scalability. Hence, future research should detail the scalability of the identified business models to be able to better assess their adoption and chances of success.

## 7.3 Conclusion

The electricity market is undergoing many changes in the past decade. Climate change is influencing consumer behaviour, decentralization drives the adoption of RES, electrification increases overall demand and digitalization introduces new opportunities for market optimization. Yet, these trends also introduce challenges; namely a shift in the load curve and a tendency to zero marginal cost caused by the increasing usage of RES. Parallel to these trends in the electricity market, the world is experiencing a new technology, the blockchain. It enables digital, decentralized transactions and is praised as the technology that will disrupt many transaction-based businesses. Hence, this thesis aimed at answering the research questions what kind of blockchain-based business models within the electricity market exist, how these business models affect the electricity market and its value chain, and what needs to be considered when implementing a blockchain-based P2P energy-trading platform. By utilizing a case-study approach, 21 case studies were analysed and 7 blockchain-based business models were identified. The retailer, the REC-incentive scheme, and the OTC-trading platform utilise blockchain characteristics to disintermediate in the value chain, redesign and automate processes, and cut administrative costs. The platforms that operate in the flexibility- and P2P energy-trading markets present new means of addressing the current market challenges by decentralizing the energy supply and balancing the grid through demand response. Blockchain-based crowd-sale/funding further advances the decentralisation of the electricity market by minimising the entry barrier into their field of application. Transparency regarding the procured energy mix is a novel transparency and accountability tool to reveal the actual share of green power in energy consumption, influencing consumer behaviour and increasing producers' accountability. The analysis of the EMPOWER smart grid pilot in Hvaler regarding a possible P2P energy trading platform has shown that the market and pricing mechanisms need to be properly aligned to set the right incentives for the consumers. In such as setting, the blockchain technology can be utilized to execute the necessary market mechanisms in an efficient manner through smart contracts. Although the traditional electricity market is not yet disrupted, established companies should be on the alert. As this thesis has shown, there are many business models that have the power to substantially change the electricity market value chain.

# References

Accenture. (2014). *Digital Utility: Transforming for value and growth*. Retrieved from https://www.accenture.com/us-en/insight-digital-utility-infographic

Alliander, & Spectral. (2017a). Blockchain: Jouliette @ De Ceuvel. Retrieved November 17, 2017, from https://www.jouliette.net/blockchain.html

Alliander, & Spectral. (2017b). Jouliette at De Ceuvel. Retrieved November 14, 2017, from https://www.jouliette.net/

Amit, R., & Zott, C. (2001). Value Creation in E-Business. *Strategic Management Journal*, *22*, 493–520. https://doi.org/10.1002/smj.187

Appelbaum, A. (2017). A microgrid grows in Brooklyn — is this the future of energy? Retrieved November 13, 2017, from https://www.greenbiz.com/article/microgrid-grows-brooklyn-future-energy

Appunn, K. (2016). Re-dispatch costs in the German power grid. Retrieved October 20, 2017, from https://www.cleanenergywire.org/factsheets/re-dispatch-costs-german-power-grid

Baran, P. (1964). On distributed Communications: I. Introduction to distributed communications networks. *IEEE Transactions on Communications Systems*, *12*(1), 1–9. https://doi.org/10.1109/TCOM.1964.1088883

Beck, R., Czepluch, J. S., Lollike, N., & Malone, S. (2016). Blockchain – the Gateway To Trust- Free Cryptographic Transactions. *Twenty-Fourth European Conference on Information Systems (ECIS)*, 5–16.

Bellini, M. (2017). Norwegian solar market sees the light with 366% growth in 2016. *Pv Magazine*. Retrieved from https://www.pv-magazine.com/2017/03/06/norwegian-solar-market-sees-the-light-with-366-growth-in-2016/

Bertsch, J., Elberg, C., Helgeson, B., Knaut, A., & Tode, C. (2017). *Disruptive Potential in the German Electricity System – an Economic Perspective on Blockchain*. Köln. Retrieved from http://www.ewi.research-scenarios.de/cms/wp-content/uploads/2017/07/Disruptive_Potential_in_the_German_Electricity_System_–_an_Economic_Perspective_on_Blockchain.pdf

Block, C., Neumann, D., & Weinhardt, C. (2008). A market mechanism for energy allocation in micro-CHP grids. *Proceedings of the Annual Hawaii International Conference on System Sciences*, (May 2006), 1–11. https://doi.org/10.1109/HICSS.2008.27

blog.stromhaltig. (n.d.). *GrünStromJeton: Von Ökostrom zu Grünstrom*. Retrieved from https://de.slideshare.net/zoernert/grnstromjeton-verdienen-am-stromverbrauch-mit-der-blockchain

Botsman, R., & Rogers, R. (2010). *What's Mine Is Yours: The Rise of Collarborative Consumption*. HarperBusiness.

Bovlabs. (n.d.). *Light in every home Empowering community for self-reliant energy by creating a marketplace to trade energy peer to peer*.

Brandon, G. (2017). CAN THE BLOCKCHAIN SCALE? Retrieved December 18, 2017, from https://due.com/blog/can-the-blockchain-scale/

Brosens, T. (2017). Why Bitcoin transactions are more expensive than you think. Retrieved December 17, 2017, from https://think.ing.com/opinions/why-bitcoin-transactions-are-more-expensive-than-you-think/

Burger, C., Kuhlmann, A., Richard, P., & Weinmann, J. (2016). *Blockchain in the energy transition. A survey among decision-makers in the German energy industry*. Berlin. Retrieved from https://www.dena.de/fileadmin/dena/Dokumente/Meldungen/dena_ESMT_Studie_blockchain_englisch.pdf

Burnett, M. W. (2016). Energy Storage and the California "Duck Curve." Retrieved October 13, 2017, from http://large.stanford.edu/courses/2015/ph240/burnett2/

CAISO. (2016). *What the duck curve tells us about managing a green grid* (Vol. Fact Sheet). https://doi.org/CommPR/HS/10.2013

Cameron-Huff, A. (2017). How Tokenization Is Putting Real-World Assets on Blockchains. Retrieved June 6, 2017, from http://www.nasdaq.com/article/how-tokenization-is-putting-real-world-assets-on-blockchains-cm767952

Castor, A. (2017). A (Short) Guide to Blockchain Consensus Protocols. *CoinDesk*. Retrieved from https://www.coindesk.com/short-guide-blockchain-consensus-protocols/

CDP. (2017). About us. Retrieved October 7, 2017, from https://www.cdp.net/en/info/about-us

CGI Group. (2017). *Opportunities for blockchain in the energy sector*.

Chesbrough, H. (2010). Business model innovation: Opportunities and barriers. *Long Range Planning*, *43*(2–3), 354–363. https://doi.org/10.1016/j.lrp.2009.07.010

Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and Corporate Change*, *11*(3), 529–555. https://doi.org/10.1093/icc/11.3.529

Cian, E. De, Lanzi, E., & Roson, R. (2007). *The Impact of Temperature Change on Energy Demand : A Dynamic Panel Analysis* (4 No. 47). Retrieved from http://ssrn.com/abstract=984237%0AThe

Codagnone, C., & Martens, B. (2016). *Scoping the Sharing Economy : Origins , Definitions , Impact and Regulatory Issues Table of Contents*. *JRC Technical Reports*.

Cohn, A., West, T., & Parker, C. (2017). Smart After All: Blockchain, Smart Contracts, Parametric Insurance, and Smart Energy Grids. *Georgetown Law Technology Review*, *273*, 273–304. Retrieved from https://www.georgetownlawtechreview.org/smart-after-all-blockchain-smart-contracts-parametric-insurance-and-smart-energy-grids/GLTR-04-2017/

Conjoule GmbH. (2017). Conjoule: How it works. Retrieved November 5, 2017, from http://conjoule.de/en/home/

Coyne, B. (2017). Can blockchain unlock demand-side response? *Theenergyst.com*. Retrieved from https://theenergyst.com/can-blockchain-unlock-demand-side-response/

Croman, K., Decker, C., Eyal, I., Gencer, A. E., Juels, A., Kosba, A., … Wattenhofer, R. (2016). On scaling decentralized blockchains (A position paper). *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 9604 LNCS*, 106–125. https://doi.org/10.1007/978-3-662-53357-4_8

Crunchbase. (2017). Companies.

Danish Energy Agency. (2011). Securing Denmark's energy future. Retrieved October 1, 2017, from http://en-press.ens.dk/pressreleases/securing-denmarks-energy-future-1781422

Danzi, P., Angjelichinoski, M., Stefanović, Č., & Popovski, P. (2017). Distributed Proportional-Fairness Control in MicroGrids via Blockchain Smart Contracts. *Paper Submitted to "IEEE Smartgridcomm 2017."* Retrieved from http://arxiv.org/abs/1705.01453

De Vos, K. (2015). Negative Wholesale Electricity Prices in the German, French and Belgian Day-Ahead, Intra-Day and Real-Time Markets. *Electricity Journal*, *28*(4), 36–50. https://doi.org/10.1016/j.tej.2015.04.001

Degode, A. (2016). *Blockchain technologies as enabler for decentralized and regional energy balancing services*. University of Freiburg.

Del Rowe, S. (2016). The Rise of the Sharing Economy: Although the term itself might be vague, the fundamental principles of the disruptive business model are here to stay. *CRM Magazine*, *10*(22).

Deloitte. (2016). Blockchain applications in energy trading, 1–2.

Deloitte. (2017a). Blockchain technology – Creating a decentralized future. Retrieved November 5, 2017, from Blockchain technology – Creating a decentralized future

Deloitte. (2017b). *Continuous interconnected supply chain: Using Blockchain & Internet-of-Things in supply chain traceability*.

Demil, B., & Lecocq, X. (2010). Business model evolution: In search of dynamic consistency. *Long Range Planning*, *43*(2–3), 227–246. https://doi.org/10.1016/j.lrp.2010.02.004

Denholm, P., O'Connell, M., Brinkman, G., & Jorgenson, J. (2015). *Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart*. *Technical Report*. Retrieved from http://www.nrel.gov/docs/fy16osti/65453.pdf

Drescher, D. (2017). *Blockchain Basics: A Non-Technical Introduction in 25 Steps*. Apress. https://doi.org/10.1007/978-1-4842-2604-9

Drift Marketplace. (2017a). How it works. Retrieved November 5, 2017, from https://www.joindrift.com/how-it-works

Drift Marketplace. (2017b). Why 7 day billing? Retrieved from https://thedriftblog.net/2017/06/01/why-7-day-billing/

Dubosson-Torbay, M., Osterwalder, A., & Pigneur, Y. (2002). eBusiness Model Design, Classification, and Measurements. *Thunderbird International Business Review*, *44*(1), 5–23. https://doi.org/10.1002/tie.1036

Ecofys. (2014). *Flexibility options in electricity systems*. Berlin. Retrieved from https://www.ecofys.com/files/files/ecofys-eci-2014-flexibility-options-in-electricity-systems.pdf

Electron. (2017). Our Products. Retrieved November 12, 2017, from http://www.electron.org.uk/#our_products

EMPOWER H2020. (n.d.). EMPOWER. Retrieved November 22, 2017, from http://empowerh2020.eu/the-project/

Enbloc. (2017). *Energy Trading Platform*.

Energi Mine. (2017a). *Decentralizing global energy markets by rewarding energy efficient behavior: Power to the People*.

Energi Mine. (2017b). Energi Token. Retrieved November 17, 2017, from https://energitoken.com/

EY. (2017). EY advancing future of transportation with launch of blockchain-based integrated mobility platform. Retrieved September 30, 2017, from http://www.ey.com/gl/en/newsroom/news-releases/news-ey-advancing-future-of-transportation-with-launch-of-blockchain-based-integrated-mobility-platform

Federico, T. (2016). BLOCKCHAIN IN DER PRAXIS - ENERGY.

Follow My Vote. (n.d.). Blockchain Technology in Online Voting. Retrieved January 24, 2017, from https://followmyvote.com/online-voting-technology/blockchain-technology/

Fraunhofer-Institut für Solare Energiesysteme. (2016). Electricity generation in Germany in 2015. Retrieved October 1, 2017, from https://www.energy-charts.de/energy_pie.htm?year=2015

Garzik, J. (2015). *Public versus Private Blockchains. Part 1: Permissioned Blockchains*.

Gassmann, O., Frankenberger, K., & Csik, M. (2014). *Revolutionizing the Business Model - St. Gallen Business Model Navigator* (Vol. 18). https://doi.org/10.1007/978-3-319-01056-4_7

Gramoli, V. (2016). On the Danger of Private Blockchains, (ii), 1–4. Retrieved from https://www.zurich.ibm.com/dccl/papers/gramoli_dccl.pdf

Greeneum. (2017). *GREENEUM Global Energy Networks Whitepaper*.

Greenhouse, S. (2016). The Whatchamacallit Economy. *The New York Times*. Retrieved from https://www.nytimes.com/2016/12/16/opinion/the-whatchamacallit-economy.html

Grid+. (2017). *Welcome to the Future of Energy*.

Hagström, L., & Dahlquist, O. (2017). *Scaling blockchain for the energy sector*. Uppsala Universitet. Retrieved from https://uu.diva-portal.org/smash/get/diva2:1118117/FULLTEXT01.pdf

Hall, S., & Roelich, K. (2016). Business model innovation in electricity supply markets: The role of complex value in the United Kingdom. *Energy Policy*, *92*, 286–298. https://doi.org/10.1016/j.enpol.2016.02.019

Holm, Ø. (2015). *National Survey Report of PV Power Applications in Norway*.

Horta, J., Kofman, D., & Menga, D. (2016). *Novel paradigms for advanced distribution grid energy management*. Paris.

Iacob, N. M., & Moise, M. L. (2015). Centralized vs. Distributed Databases. Case Study. *Academic Journal of Economic Studies*, *1*(4), 119–130.

IEA. (2017). Renewables 2017. Retrieved November 17, 2017, from https://www.iea.org/publications/renewables2017/

Ilic, D., Da Silva, P. G., Karnouskos, S., & Griesemer, M. (2012). An energy market for trading electricity in smart grid neighbourhoods. In *6th IEEE International Conference on Digital Ecosystems and Technologies (DEST)* (pp. 1–6). Campione d'Italia. https://doi.org/10.1109/DEST.2012.6227918

Imbault, F., Swiatek, M., De Beaufort, R., & Plana, R. (2017). The green blockchain: Managing decentralized energy production and consumption. *Conference Proceedings - 2017 17th IEEE International Conference on Environment and Electrical Engineering and 2017 1st IEEE Industrial and Commercial Power Systems Europe, EEEIC / I and CPS Europe 2017*, (August). https://doi.org/10.1109/EEEIC.2017.7977613

Indigo Advisory Group. (n.d.). Blockchain in Energy and Utilities: Use Cases, Vendor Activity and Market Analysis. Retrieved June 8, 2017, from https://www.indigoadvisorygroup.com/blockchain

Institute of network cultures. (n.d.). Beyond distributed and decentralized: what is a federated network? Retrieved January 23, 2017, from http://networkcultures.org/unlikeus/resources/articles/what-is-a-federated-network/

International Energy Agency. (2017a). *Energy Policies of IEA Countries: Norway 2017 Review*. https://doi.org/10.1038/news061218-10

International Energy Agency. (2017b). *Energy Technology Perspectives 2017 - Executive Summary: Catalysing Energy Technology Transformations*.

https://doi.org/10.1787/energy_tech-2014-en

International Energy Agency. (2017c). *Global EV Outlook 2017: Two million and counting*. https://doi.org/10.1787/9789264278882-en

Jackson, T. (2017, September 14). SA's The Sun Exchange crowdfunds solar at Knysna Elephant Park. *Disrupt Africa*. Retrieved from http://disrupt-africa.com/2017/09/sas-the-sun-exchange-crowdfunds-solar-at-knysna-elephant-park/

Johnson, L. P., Isam, A., Gogerty, N., & Zitoli, J. (2015). A Renewable Energy Powered Trustless Value Transfer Network Connecting the Blockchain to the Sun to Save the Planet, 1–16. https://doi.org/10.2139/ssrn.2702639

Kasireddy, P. (2017). Blockchains don't scale. Not today, at least. But there's hope. Retrieved December 18, 2017, from https://hackernoon.com/blockchains-dont-scale-not-today-at-least-but-there-s-hope-2cb43946551a

Konashevych, O. (2016). Advantages and Current Issues of Blockchain Use in Microgrids. *Electronic Modeling - International Scientific-Theoretical Journal of Pukhov Institute for Modeling in Energy Engineering, NAS of Ukraine*, *38*(2), 93–104. Retrieved from http://www.emodel.org.ua/images/em/38-2/Konashevych.pdf%5Cnhttp://www.emodel.org.ua/index.php/en/51-archive/2016-рік/38-2/864-38-2-7-e.html

Lacey, S. (2017). Drift Is a New Startup Applying Peer-to-Peer Trading to Retail Electricity Markets. Retrieved November 5, 2017, from https://www.greentechmedia.com/articles/read/drift-is-a-startup-applying-peer-to-peer-trading-to-retail-electricity#gs.WI2gkuI

Lilic, J., & Lundfall, M. (2016). *Energy meets Blockchain*.

Lipton, A. (2017). *Blockchains and Distributed Ledgers in Retrospective and Perspective*. Cambridge, MA. Retrieved from http://arxiv.org/abs/1703.01505

LO3 Energy. (n.d.). *Distributed grid solutions that bring people, utilities and technology together*.

Lombardi, P., & Schwabe, F. (2017). Sharing economy as a new business model for energy storage systems. *Applied Energy*, *188*(February), 485–496. https://doi.org/10.1016/j.apenergy.2016.12.016

Mattila, J., Seppälä, T., Naucler, C., Stahl, R., Tikkanen, M., Badenlid, A., & Seppälä, J. (2016). *Industrial Blockchain Platforms : An Exercise in Use Case Development in the Energy Industry* (ETLA Working Papers No. 43). https://doi.org/10.1017/CBO9781107415324.004

McKinsey. (2016). The digital utility: New opportunities and challenges. Retrieved September 19, 2017, from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-digital-utility-new-opportunities-and-challenges

Mengelkamp, E., Gärttner, J., Rock, K., Kessler, S., Orsini, L., & Weinhardt, C. (2017). Designing microgrid energy markets. A case study: The Brooklyn Microgrid. *Applied*

*Energy*. https://doi.org/10.1016/j.apenergy.2017.06.054

Mengelkamp, E., Notheisen, B., Beer, C., Dauer, D., & Weinhardt, C. (2017). A blockchain-based smart grid: towards sustainable local energy markets. *Computer Science - Research and Development*, 1–8. https://doi.org/10.1007/s00450-017-0360-9

Merz, M. (2016). Potential of the Blockchain Technology in Energy Trading. In D. Burgwinkel (Ed.), *Blockchain technology Introduction for business and IT managers* (pp. 51–98). Berlin: De Gruyter Oldenbourg. https://doi.org/10.1515/9783110488951

Meunier, S. (2016, December). Blockchain technology - a very special kind of Distributed Database.

Microgrid News. (2016). "It's Like The Early Days of the Internet," Blockchain-based Brooklyn Microgrid Tests P2P Energy Trading. Retrieved November 13, 2017, from http://microgridmedia.com/its-like-the-early-days-of-the-internet-blockchain-based-brooklyn-microgrid-tests-p2p-energy-trading/

Mihaylov, M., Jurado, S., & Avellana, N. (2014). NRGcoin: Virtual Currency for Trading of Renewable Energy in Smart Grids. In *11th International Conference on the European Energy Market* (pp. 1–6).

Mihaylov, M., Razo-Zapata, I., Rădulescu, R., & Nowé, A. (2016). Boosting the Renewable Energy Economy with NRGcoin. In *4th International Conference on ICT for Sustainability (ICT4S 2016)* (pp. 299–230). Atlantis Press.

Movable Type. (n.d.). SHA-256 Cryptographic Hash Algorithm. Retrieved September 9, 2017, from https://www.movable-type.co.uk/scripts/sha256.html

MyBit. (2017). *Mybit unlocking billions in Iot revenues*.

Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. https://doi.org/10.1007/s10838-008-9062-0

Nord Pool AS. (2017). Historical Market Data. Retrieved November 22, 2017, from https://www.nordpoolgroup.com/historical-market-data/

Norgesnett. (2017). Effektbasert nettleie. Retrieved November 22, 2017, from https://norgesnett.no/nettleie/#/effektbasert-nettleie/

NRGcoin. (n.d.). Frequently Asked Questions. Retrieved November 24, 2017, from https://www.nrgcoin.org/faq

NVE. (2016). Electricity disclosure 2015. Retrieved October 1, 2017, from https://www.nve.no/energy-market-and-regulation/retail-market/electricity-disclosure-2015/

NVE. (2017). Network tariffs. Retrieved December 2, 2017, from https://www.nve.no/energy-market-and-regulation/network-regulation/network-tariffs/

Onetti, A., Zucchella, A., Jones, M. V., & McDougall-Covin, P. P. (2012). Internationalization, innovation and entrepreneurship: Business models for new technology-based firms. *Journal of Management and Governance*, *16*(3), 337–368. https://doi.org/10.1007/s10997-010-9154-1

Osterwalder, A. (2004). *The Business Model Ontology: A Proposition in a Design Science Approach*. University of Lausanne.

Pilkington, M. (2015). Blockchain Technology: Principles and Applications. *Research Handbook on Digital Transformations*, 1–39. Retrieved from http://papers.ssrn.com/abstract=2662660

Pilz, M., & Al-Fagih, L. (2017). Game-Theoretic Approaches to Energy Trading: A Survey, 1–10. Retrieved from http://arxiv.org/abs/1702.02915

Plewnia, F., & Guenther, E. M. (2017). A Collaborative Energy System - How the Sharing Economy Affects the Energy Sector. *Academy of Management Proceedings*, *2017*(1), 17694. https://doi.org/10.5465/AMBPP.2017.17694abstract

PONTON. (2017a). Enerchain P2P Trading Project. Retrieved from https://enerchain.ponton.de/index.php/21-enerchain-p2p-trading-project

PONTON. (2017b). Enerchain project enters proof of concept phase. Retrieved January 1, 2017, from https://enerchain.ponton.de/index.php/32-enerchain-project-enters-proof-of-concept-phase

Power Ledger. (2017). Happy to explain Power Ledger in more detail below and address some your comments. Retrieved November 13, 2017, from https://medium.com/@PowerLedger_io/happy-to-explain-power-ledger-in-more-detail-below-and-address-some-your-comments-aea4120f7fb4

Power Ledger. (2017). Trading Sunshine — Nest and Power Ledger bring renewable energy trading to Launceston. Retrieved November 13, 2017, from https://medium.com/power-ledger/trading-sunshine-nest-and-power-ledger-bring-renewable-energy-trading-to-launceston-656c104d2f4a

Power Ledger. (2017). *Whitepaper*. Retrieved from https://powerledger.io/media/Power-Ledger-Whitepaper-v3.pdf

Prosume. (2017a). Prosume. Retrieved November 18, 2017, from http://prosume.io/

Prosume. (2017b). *White Paper*.

PwC. (2016). *Blockchain – an opportunity for energy producers and consumers?* Retrieved from www.pwc.com/utilities

RE100. (2017). RE100. Retrieved October 7, 2017, from http://there100.org/re100

Renaudin, H. (2017a). Grid+ Business Model: A low-cost utility in the short term, a Nest for energy retail in the long run. Retrieved November 12, 2017, from https://icoinsiders.io/grid-business-model-a-low-cost-utility-in-the-short-term-a-nest-for-energy-retail-in-the-long-fbfd5ed9a041

Renaudin, H. (2017b). Grid+ Business Model: A low-cost utility in the short term, a Nest for energy retail in the long run.

Reuters. (2017, April 14). Uber's revenue hits $6.5 billion in 2016, still has large loss. *Reuters*. Retrieved from https://www.reuters.com/article/us-uber-tech-results/ubers-revenue-hits-6-5-billion-in-2016-still-has-large-loss-idUSKBN17G1IB

Richter, M. (2012). Utilities' business models for renewable energy: A review. *Renewable and Sustainable Energy Reviews, 16*(5), 2483–2493. https://doi.org/10.1016/j.rser.2012.01.072

Rodriguez-Molina, J., Martinez-Nunez, M., Martinez, J. F., & Perez-Aguiar, W. (2014). Business models in the smart grid: Challenges, opportunities and proposals for prosumer profitability. *Energies*, *7*(9), 6142–6171. https://doi.org/10.3390/en7096142

Ross, K. (2017a). Blockchain token for renewables sharing. Retrieved November 12, 2017, from http://www.powerengineeringint.com/articles/print/volume-25/issue-9/features/blockchain-token-for-renewables-sharing.html

Ross, K. (2017b, September 27). Blockchain Token to Share Renewable Energy Unveiled. *RenewableEnergyWorld.com*. Retrieved from http://www.renewableenergyworld.com/articles/2017/09/blockchain-token-to-share-renewable-energy-unveiled.html

Rousselet, V. (2014). Sharing and owning: The rise of the hybrid consumer. *Market Leader*, *Q4*, 24–27.

Rusitschka, S. (2017). Token Model for Energy — Part 1: Review of the Power Ledger token model. Retrieved November 5, 2017, from https://medium.com/@sebnem/token-model-for-energy-part-1-c47b6f926bc3

Shen, J., Jiang, C., & Li, B. (2015). Controllable load management approaches in smart grids. *Energies*, *8*(10), 11187–11202. https://doi.org/10.3390/en81011187

Sikorski, J. J., Haughton, J., & Kraft, M. (2016). Blockchain technology in the chemical industry : Machine-to-machine electricity market. *Applied Energy*, *195*, 234–246. Retrieved from https://como.cheng.cam.ac.uk/preprints/c4e-Preprint-178.pdf

Smart Energi. (n.d.). VI KJØPER SOLSTRØMMEN DIN FOR 80 ØRE! Retrieved November 22, 2017, from https://www.smartenergi.com/produkter/80-ore/

SolarCoin. (n.d.-a). FAQs. Retrieved November 24, 2014, from https://solarcoin.org/en/frequently-asked-questions

SolarCoin. (n.d.-b). SolarCoin Presentation. Retrieved November 24, 2017, from https://solarcoin.org/solarcoin-presentation

SolarIoT. (2017). Cooperative Solar Energy Smart Grid. Retrieved November 14, 2017, from https://www.solariot.xyz/

sonnen GmbH. (2017, May). Stabilizing the power grid with households: TenneT and sonnen are pioneering the networking of storage batteries with blockchain technology | sonnen.

Spectral. (2017). Projects. Retrieved November 17, 2017, from https://spectral.energy/projects/

State of the DApps. (n.d.). A curated list of 854 decentralized apps for ethereum. Retrieved December 3, 2017, from https://www.stateofthedapps.com/

Statistics Norway. (2016). Electricity. Retrieved October 1, 2017, from https://www.ssb.no/en/energi-og-industri/statistikker/elektrisitet/aar

Stromhaltig.de. (2013). Grünstrom Index (GSI). Retrieved November 24, 2017, from http://mix.stromhaltig.de/gsi/

Swan, M. (2015). *Blockchain: Blueprint for a New Economy*. (T. McGovern, Ed.). Sebastopol: O'Reilly Media. https://doi.org/10.1017/CBO9781107415324.004

Tai, X., Sun, H., & Guo, Q. (2016). Electricity Transactions and Congestion Management Based on Blockchain in Energy Internet. *Power System Technology*, *40*(12), 3630–3638. https://doi.org/10.13335/j.1000-3673.pst.2016.12.002

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

TenneT. (2017). Blockchain Technology. Retrieved November 19, 2017, from https://www.tennet.eu/our-key-tasks/innovations/blockchain-technology/

TenneT, & sonnen GmbH. (2017, November 2). Europaweit erstes Blockchain-Projekt zur Stabilisierung des Stromnetzes startet : TenneT und sonnen erwarten Ergebnisse 2018. *Press Release*.

The Economist. (2015). The great chain of being sure about things. *The Economist*, 21–24. https://doi.org/10.3763/cpol.2008.0536

The Sun Exchange. (n.d.). *High Level Pitch Deck: Welcome to the Age of Solar Powered Money*.

The Sun Exchange. (2017a). *Solar Crowd-Investment*. Retrieved from https://thesunexchange.com/sites/default/files/sws_sec_15kw_solar_co-operative_information.pdf

The Sun Exchange. (2017b). The Solar Panel Sharing Economy. Retrieved November 19, 2017, from https://thesunexchange.com/

Timmers, P. (1998). Business Models for Electronic Markets. *Journal on Electronic Markets*, *8*(2), 3–8. https://doi.org/10.1080/10196789800000016

U.S. Environmental Protection Agency. (2017). Climate Impacts on Energy. Retrieved October 7, 2017, from https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-energy_.html

Umweltbundesamt. (2017). Strom- und Wärmeversorgung in Zahlen. Retrieved October 1, 2017, from http://www.umweltbundesamt.de/themen/klima-energie/energieversorgung/strom-waermeversorgung-in-zahlen#Strommix

UVEK. (2017). Die wichtigsten Massnahmen im Energiegesetz. Retrieved October 8, 2017, from https://www.uvek.admin.ch/uvek/de/home/energie/energiestrategie-2050/uebersicht-massnahmen.html

Valdman, B. (2016, August 22). Why the Energy Sector Needs a Sharing Economy. *Sustainable Brands Issue in Focus*. Retrieved from http://www.sustainablebrands.com/news_and_views/business_models/bert_valdman/why_energy_sector_need_sharing_economy

Van Der Schoor, T., & Scholtens, B. (2015). Power to the people: Local community initiatives and the transition to sustainable energy. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2014.10.089

Wangensteen, I. (2012). *Power System Economics - the Nordic Electricity Market* (2nd ed.). Trondheim: Tapir Academic Press.

Wattcoin Labs. (n.d.-a). Energy Efficiency for the Consumer. Retrieved November 24, 2017, from https://wattcoin.com/energy-efficiency.html

Wattcoin Labs. (n.d.-b). Utility & Smart Grid Systems. Retrieved November 24, 2017, from https://wattcoin.com/smart-grids.html

WEC, CJBS, & CISL. (2014). *Climate Change: Implications for the Energy Sector*. Retrieved from www.cisl.cam.ac.uk/ipcc

WePower Network. (2017a). Homepage. Retrieved November 18, 2017, from https://wepower.network/

WePower Network. (2017b). *WePower: Green Energy Network*.

World Economic Forum. (2017). *The Future of Electricity: New Technologies Transforming the Grid Edge*. *World Economic forum*. Retrieved from https://www.weforum.org/reports/the-future-of-electricity-new-technologies-transforming-the-grid-edge

World Energy Council. (2017). The Developing Role of Blockchain, 0–21. Retrieved from https://www.worldenergy.org/wp-content/uploads/2017/11/WP_Blockchain_Exec-Summary_final.pdf

Yunus, M., Moingeon, B., & Lehmann-Ortega, L. (2010). Building social business models: Lessons from the grameen experience. *Long Range Planning*, *43*(2–3), 308–325. https://doi.org/10.1016/j.lrp.2009.12.005

Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research. *Journal of Management*, *37*(4), 1019–1042. https://doi.org/10.1177/0149206311406265

# Appendices

## A) Concepts of network architectures by Paul Baran

In this thesis, network systems play an important role in discussing blockchain development within the energy sector. The following elaboration on concepts of network architecture likewise applied to the decentralisation of the electricity market respectively to distributed RES.

Modern network systems emerged out of the development of information and communications technologies. Thinking of telegraphs and telecommunication, these technologies were centralised early on. During the Cold War and the imminent threat of nuclear war, the researcher Paul Baran first defined three concepts of network architectures in 1964. His intention was to discuss how telecommunication networks could be improved in such way that a single attack on the centralised infrastructure, which would shut down all U.S. communications, could be prevented (Baran, 1964). As a solution, Baran proposed distributing important parts of the network. This way, if one part of the network fails to work due to external attacks, other parts are fail-safe and will continue to work.

Before looking further into these concepts, some terminology needs to be introduced (Institute of network cultures, n.d.): A network is a collection of interlinked nodes that exchange information; a node or station is an agent and a part of the network – for instance, a user or a computer; a link is a connection between two nodes; and a server is a node that has connections to a large number of other nodes.

In other words, a network is an interconnected set of nodes that can send and receive information. The nodes, servers and the links can be organised in different ways. The initial network system is centralised (a). All nodes are linked to one server and can therefore exchange data with each other. In a decentralised network (b), there are several servers which are in turn connected to each other and to a certain number of nodes. Hence, the network does not rely solely on one server. The distributed network (c) is characterised as not having any servers; instead, each station is connected to other stations.

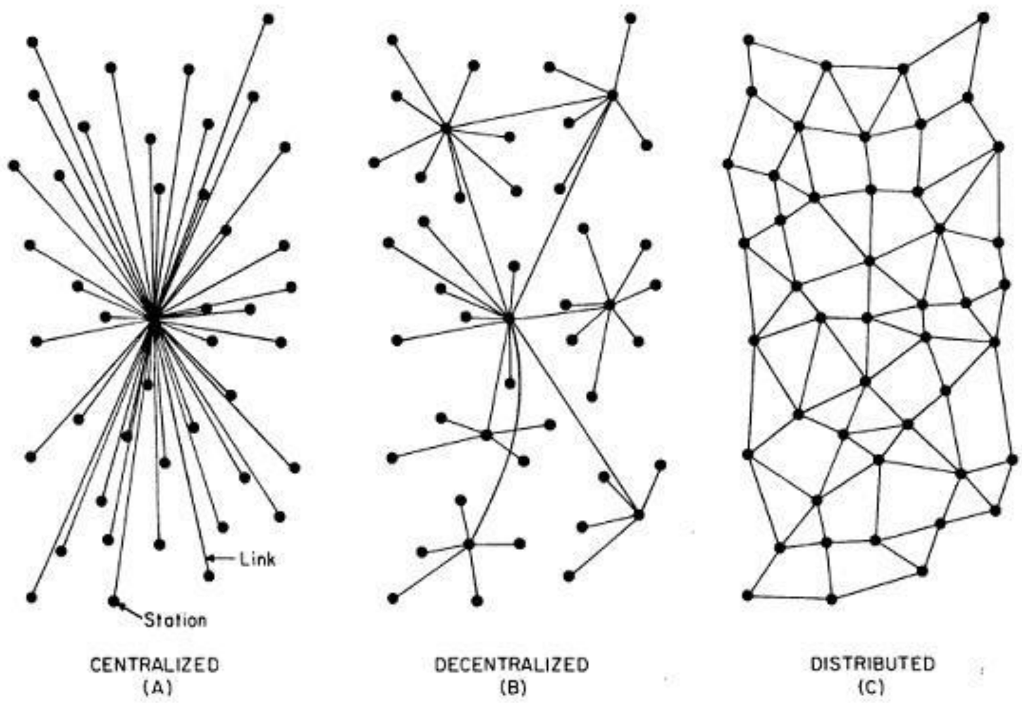


*Figure 7: Structures of communication networks (Baran, 1964).*

# B) Blockchain technology

## *Blockchain cryptography*

In order to ensure the security in a network, the blockchain contains some cryptographic protections. The following is a summary of an article by The Economist (2015), which explains the cryptographic protection:

1. Each node has its unique identification: The underlying function of blockchain cryptography is that each node is assigned a public key, shared with the network, and a private key, used to sign transactions. To initiate and request a transaction, the recipient must first send his public key to the sender.
2. The information, containing the originator's and recipient's data and the content of the transaction, is combined with other transactions requested at the same time to build a block. An algorithm creates a unique hash, a string of digits and letters of fixed length, for every transaction. All the hash values of the transactions in one block are further combined following a system called hash or the Merkle tree. This block with a combined hash value, called the Merkle root, is now encrypted and sent to every node in the network.

3. Next, the block is validated. The validation is processed by so-called miners, members of the network with high levels of computing power, who compete against each other by solving a complex coded puzzle, the nonce. In the case of the cryptocurrency bitcoin, the first miner who solves the puzzle and thereby validates the block receives a reward, here in the form of bitcoin, for his work.
4. After the validation, the block gets a timestamp and is added to the previous block, along with the hash value of the previous block’s header. The current block’s header now contains the hash value of the previous block, its own Merkle root and the timestamp. This process finally chains the blocks together and forms the blockchain.
5. Then, the transaction is confirmed. All transactions can be tracked transparently and are inedible.

The transfer is triggered by the hash signature. The public key is a cryptographically generated address stored in the blockchain, and each transaction is associated with an address (Pilkington, 2015).

In addition, the validation process safeguards that a transaction cannot be modified unless the specific block and the following blocks which record the transaction are modified as well.

### *Centralised and distributed databases and ledgers*

In information technology, two major approaches towards databases exist: centralised and distributed database management systems. Which database is used depends on the application solution and requirements as well as the infrastructure characteristics.

Centralised relational database management systems (RDBMS) manage, store and maintain the data in a single location. Storage devices are thus connected to a single, common processor (Lipton, 2017). The databases are programmed and managed in a domain-specific language called structured query language (SQL). With SQL, data can be accessed, inserted, queried, updated and deleted. Access to the database is strongly controlled. On the one hand, central data integration ensures a consistent management of data and simple management of transactions. On the other hand, RDBMSs have high communication costs and are vulnerable to an error that can block database access, thereby lowering reliability and availability (Iacob & Moise, 2015).

A distributed database (DDBMS) is different from a centralised one as the storage devices are spread across a network and not attached to a common processing unit. The data in the network are periodically synchronised and updated across the nodes. Moreover, several participants may be granted access to the database and to process the data (Lipton, 2017). Due to their distributed structure, DDBMSs are less error-prone and more robust against failures as data is usually replicated locally on all nodes. As data are closer to where they are used, DDBMSs have lower communication costs and a faster response rate as requests can be answered more quickly. Furthermore, distributed databases can be developed and expanded in a modular way. In contrast, the overall system is more complex and can lead to an increased processing overhead as data integrity demands more network resources. This follows from fragmentation and replication of data within such networks. With regards to security, a risk persists when data need to be shared between nodes (Iacob & Moise, 2015).

Consensus and immutability are not unique to DLs, but some distributed databases also incorporate those parameters. The main distinguishing factors according to Meunier (2016) are the decentralised access control compared to a logically centralised one in distributed databases and, as a corollary, ‘the ability to secure transactions in competing environments, without trusted third parties’ (Meunier, 2016).

# C) Longlist of cases

*Table 10: Longlist of cases*

| Case | Description | Source | Included in Analysis | Reason for omission |
|---|---|---|---|---|
| **4NEW** | 4NEW is a United Kingdom company that owns and operates Waste to Energy treatment plants. | Crunchbase | no | Wrong focus - industry |
| **AI BlockChain** | AI BlockChain, an artificial intelligent blockchain, offers forefront security on a distributed system for contract lifecycle management. | Crunchbase | no | Wrong focus - industry |
| **Ayasta Technologies** | Ayasta is a technology and design centric company focused on digitising electrical. | Crunchbase | no | Wrong focus - industry |
| **BigchainDB** | BigchainDB is a scalable blockchain database | Crunchbase | no | Wrong focus - industry |
| **Blockchain Tech LTD** | Providing seed investments in early stage startups exploring blockchain technology | Crunchbase | no | Wrong focus - industry |
| **Bovlabs Inc** | Empowering community for self-reliant energy by creating a market place to trade peer to peer, with low transaction cost and high security | Crunchbase | yes | |
| **BTL Group** | BTL offers blockchain solutions to businesses across multiple industries, in particular the finance, energy and gaming sectors. | Crunchbase | no | Wrong focus - industry |
| **ChainMind** | The Brains Behind the Blockchain | Crunchbase | no | Wrong focus - industry |
| **CLIMATECOIN** | CLIMATECOIN with a new technology called “Blockchain” could play a major role in tackling climate change.  CARBON MARKET | Crunchbase | no | Wrong focus - industry |

| | | | | |
|---|---|---|---|---|
| **Conjoule** | Conjoule is a venture capital backed start-up. | Crunchbase | yes | |
| **DAJIE Ltd** | Distributed Autonomous Joint Internet and Energy | Crunchbase | no | Not active anymore |
| **DAO IPCI** | Blockchain technology for carbon markets, environmental assets and liabilities | State of the Dapps Search (#energy) | no | Wrong focus - activity |
| **Drift** | | PwC | yes | |
| **DTCO** | Industrial Blockchain Service Provider | Crunchbase | no | Wrong focus - industry |
| **ElectriCChain** | ElectriCChain is an open solar energy generation data project with an initial focus on verifying. | Crunchbase | no | Wrong focus - activity |
| **Electron** | Electron develops distributed ledger or blockchain systems for the energy sector. | Crunchbase | yes | |
| **Enbloc** | Enbloc is a decentralized energy trading platform with the vision of creating a self-sustaining future. | Crunchbase | yes | |
| **Enerchain** | | PwC | yes | |
| **Energi Mine** | Using AI & Blockchain in the energy markets. | Crunchbase | yes | |
| **Energy Web Foundation** | Energy Web Foundation is a global non-profit organization focused on accelerating blockchain technology across the energy sector. | Crunchbase | no | Wrong focus - activity |
| **EnLedger, Corp.** | EnLedger is a blockchain tech services provider that allows people to interface with blockchains in new ways. We enable a brighter future! | Crunchbase | no | Wrong focus - industry |
| **Giga Watt** | The world’s first state of the art combined Blockchain hosting and service center. | Crunchbase | no | Wrong focus - industry |

| | | | | |
|---|---|---|---|---|
| **Green Running Ltd (creators of Verv)** | Creators of Verv, an advanced home energy assistant. Pioneers of peer-2-peer energy trading in the UK using its AI tech + blockchain | Crunchbase | no | No pilot yet |
| **Greeneum** | Greeneum Network leverages blockchain technology, smart contracts and artificial intelligence to decentralise the clean energy marketplace. | Crunchbase | yes | |
| **Grid Singularity** | | State of the Dapps Search (#energy; #electricity) | no | Wrong focus - activity |
| **Grid+** | Grid+, its commercial electricity retail business and eventual energy-sharing marketplace | State of the Dapps Search (#energy) | yes | |
| **GrünStromJeton** | | State of the Dapps Search (#energy) | yes | |
| **Hedgy** | Hedgy inc is a company creating applications using block chain technology, combining it with common, traditional financial items. | Crunchbase | no | Wrong focus - industry |
| **HIVE Blockchain** | One of the first crypto company. | Crunchbase | no | Wrong focus - industry |
| **ImpactPPA** | ImpactPPA is a decentralized energy platform built to disrupt renewable energy finance and accelerate clean energy production. | Crunchbase | no | Wrong focus - industry |
| **Jouliette** | | PwC | yes | |
| **MotionWerk GmbH** | Shared mobility connecting everyone. We enable the future of mobility based on blockchain solutions. (SaaS) | Crunchbase | no | Wrong focus - industry |
| **MyBit** | MyBit is a decentralized asset management platform built on Ethereum. | Crunchbase | yes | |
| **NetObjex** | NetObjex provides a Decentralized Digital Asset Management Platform as a Service using IoT and Distributed Ledger | Crunchbase | no | Wrong focus - industry |

| | | | | |
|---|---|---|---|---|
| **NRGcoin** | | PwC | yes | |
| **Pilot project by TenneT TSO and sonnen GmbH** | Stabilizing the power grid with home storage or EV loading stations. | PwC | yes | |
| **Power Ledger** | Power Ledger has developed a series of world-leading blockchain energy applications, such as its P2P energy trading application. | Crunchbase | yes | |
| **PrivacyShell Corp** | We build crypto-blockchain startups that incorporate privacy & security by design. | Crunchbase | no | Wrong focus - industry |
| **Prosume** | | PwC | yes | |
| **Sappin Global Strategies** | Sappin Global Strategies is building the next generation of global innovators | Crunchbase | no | Wrong focus - industry |
| **SmartUp Cities** | Smart City, Transportation, Energy & Mobility IoT solutions to create the smart, liveable and sustainable cities of the future | Crunchbase | no | Wrong focus - industry |
| **SolarCoin** | | PwC | yes | |
| **SolarIoT** | SolarIoT is an application for efficient cooperation in the investment, construction, and peer to peer transactions of energy. | Crunchbase | yes | |
| **Solether** | Solether is an ethereum entity, you can extend this project and add some logic to it. For example, a more advanced version of Solether could enable you to give it the ability to grow and/or replicate | State of the Dapps Search (#energy; #solar) | no | Not enough information |
| **Tennet und sonnen** | | PwC | yes | |
| **The Sky is High Crowdfunding** | The Sky is High Crowdfunding is the first and only niche financing platform for open-source New Energy technologies. | State of the Dapps Search (#energy; #renewable) | no | Wrong focus - activity |
| **The Sun Exchange** | | PwC | yes | |

| | | | | |
|---|---|---|---|---|
| **TransActive Grid** | First version of a new kind of energy market, operated by consumers, which will change the way we generate and consume electricity. | State of the Dapps Search (#energy) | yes | |
| **Turbine Plus** | Sustainable energy eco-system combined with blockchain technology. | Crunchbase | no | Not enough information |
| **Wattcoin Technologies Inc.** | Platform-as-a-service solution utilizing blockchain technology for energy consumption, behavior, payment, and value exchange | Crunchbase | no | Not active anymore |
| **WePower Network** | The first global blockchain-based green energy trading platform. | Crunchbase | yes | |
| **weXelerate GmbH** | Europe's biggest startup&innovation hub | Crunchbase | no | Wrong focus - industry |

# D) Case description along the business-model dimensions

*Table 11: Case description along the business-model dimensions*

| # | Project, Location | Objectives; Scale | Target Customer | Value Proposition | Value Chain | Value Capture |
|---|---|---|---|---|---|---|
| 1 | Bovlabs, Switzerland, USA, India | "Empowering community using DER marketplace" | Energy prosumers in US/EU and communities in developing countries. (Bovlabs, n.d.) | Energy prosumers can contribute or mirco invest into the electrifying rural communities in developing countries. (Bovlabs, n.d.) | Bovlabs wants to create a blockchain-based P2P energy trading platform running on Ethereum smart contracts. (Bovlabs, n.d.) | In the case of a community energy platform, Bovlabs intends to capture a transaction fee on every transaction. In the case of a partnership, a microgrid developer pays an annual licensing as well as transaction fees. (Bovlabs, n.d.) |
| 2 | Conjoule, Germany | Connect producers and local consumers to exchange environmental friendly energy on a P2P energy market. (Conjoule GmbH, 2017);<br>Regional | Private energy producers with PV installation and local energy consumers. | Energy producers and consumers are connected on a platform. Producers can achieve a higher remuneration for their energy than from the regular feed-in tariff and are able to analyse the PV performance "on a regular basis". Consumers may "use energy from local generators". Conjoule GmbH, 2017) | Conjoule provides the platform and marketplace on which "PV owners and energy consumers from the same region can interact". The platform incorporates algorithms and models to forecast energy consumption and production. Every electricity transaction is recorded on the platform which is based on an Ethereum blockchain. Conjoule promises efficiency and accuracy. (Conjoule GmbH, 2017; Energy Brainpool, 2017) | Conjoule states that "prosumers sell their surplus electricity and get compensated by local companies" (Conjoule GmbH, 2017); the author assumes that Conjoule charges a fee for every transaction. It is not clear how Conjoule cooperates with local retailers and DSOs to compensate for the grid infrastructure. (Conjoule GmbH, 2017) |
| 3 | Drift, USA | | Residential and small-commercial energy consumers. (Lacey, 2017) | Consumers get access to cleaner and local energy up to 10 percent cheaper than traditional electric companies. Consumers will know exactly what they are paying for as there are "no more hidden charges and contracts". Also, consumers are able to configure their own energy mix. (Drift Marketplace, 2017a) Customers aren't asked to enter into a contract with Drift to be able to use the company's service; they are flexible to enter and leave the service platform anytime. | Drift describes itself to be a "new-school power company" that works automated and paperless by using "sophisticated algorithms", software and artificial intelligence. It offers a platform connecting energy producers and consumers. Consumers access a web dashboard and choose their energy mix flexibly.<br>Drift models a daily supply curve on the basis of customers' energy usage, receiving the data from the local utility, and weather data. Drift is building and maintaining an independent network of energy generators, including power plants and RES, from which the company is procuring and buying the needed energy for its customers once the supply curve is determined. In case that demand is higher than supply, Drift resorts to high-frequency trading to reduce the price spikes. (Drift Marketplace, 2017a; Lacey, 2017) Not blockchain, but DLT | With its aggregation method, Drift is able to reduce the administrative fees by over 10 percent. In addition, it passes the electricity wholesale price rather than the retail price on to the customer. However, the customer also pays for the transmission and delivery of the electricity. Drift itself generates revenue by charging the customers a weekly subscription fee of US$ 1. Moreover, Drift pays its energy suppliers weekly as well. Thereby, the company claims to eliminate interest and other bank fees that would otherwise occur with a monthly payment. (Drift Marketplace, 2017b; Lacey, 2017) |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Electron, United Kingdom | Creating platforms for registration of UK gas and electricity supply points, a trading venue for demand-side response and P2P trading. (Electron, 2017) | No information available. Assumingly energy consumers and utilities. | Consumers will get paid to adjust their energy consumption in order to balance electricity supply and demand. (Ross, 2017a) | On the platform multiple parties may “co-ordinate and share the value of a single consumer’s action”; Integrating flexible capacities such as household battery storage or EVs, and the other addresses demand-side responses (Ross, 2017a) | No information available. |
| 5 | Enbloc, USA | Creating a holistic self-sustaining future via a decentralized energy trading platform. (Enbloc, 2017) | Energy producers and consumers. | Prosumers are offered to sell their excess energy to local consumers, who in return benefit from purchasing local, clean energy. (Enbloc, 2017) | Enbloc is enabling the payment transactions between prosumers and consumers by a (private) blockchain-based platform. The electricity transfer is registered via smart metering. The smart meters serve as the nodes of the blockchain. In the network they are executing and validating transactions. Enbloc so far only plans to provide the software. (Enbloc, 2017) | Enbloc works as a platform-as-a-service (PaaS) and will charge a marginal transaction fee for each financial transaction. (Enbloc, 2017) |
| 6 | Enerchain, Europe | Establishing a “distributed marketplace for OTC trading of wholesale energy products.” (PONTON, 2017b) | Energy producers, utilities, retailer. | PONTON, the company behind Enerchain, is planning to offer decentralized solution to support the trade of large volumes and make the operational processes more efficient to reduce the transaction costs. (PONTON, 2017a) | Enerchain’s proof-of-concept platform trades physically settled power and gas similarly to regular delivery periods. So it connects third party systems with the blockchain-based marketplace. Also Enerchain intends to integrate energy trading and risk management systems. Thanks to the blockchain-based software behind the platform, market participants could connect their trading desks directly with each other and initiate trades. (PONTON, 2017b) | No information available. |
| 7 | Energi Mine, UK | “Decentralizing global energy markets by rewarding energy efficient behaviour.” (Energi Mine, 2017b) Global | Energy producers and consumers | - Cheaper energy prices that are “truly market reflective”<br>- Reward for energy efficient behaviour (i.e. commuting by public transport) Consumers profit from automatically tender of their contracts to evaluate cheaper energy producers. Further, customers are able to pay more flexibly/regularly for their energy consumption<br>(Energi Mine, 2017a) | Energi Mine plans to build an energy eco-system using blockchain. The eco-system will include a P2P marketplace, a reward platform and a battery trading exchange. The latter will utilise tokens. Tokens are distributed for energy saving behaviour and may be used to access the P2P platform and to settle energy bills as well as access EV charging stations. On the P2P platform all producers and consumers are able to trade with each other. The platform incorporates smart contracts which allow consumers to tender their contracts. Moreover Energi Mine wants to set up a battery trading exchange. Smart metering data is consolidated for analysis by an artificial intelligence platform. (Energi Mine, 2017a) | No information available |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | GREENEUM | Creating a decentralized energy market. | "Energy producers, consumers, utilities, grid operators, and energy traders." (Greeneum, 2017) | GREENEUM's solution addresses energy market participants "to connect and optimize their performance". Producers are rewarded with green certificates and GREENEUM tokens and can get slightly higher energy prices as producers receive a transaction fee on every transaction on the grid. Consumers profit from lower energy prices and can get carbon credits through the GREENEUM platform. Utilities can get insight into more energy consumption predictions and operate plans more efficiently. Also, they get a distribution and service fee from GREENEUM on every transaction. (Greeneum, 2017) | GREENEUM wants to implement a blockchain-based platform that consists of three separate but connected systems for data management to generate predictions, energy trading and monetization. The platform utilizes smart contracts, AI, machine learning algorithms and tokenizes energy. The GREENEUM network builds on a global, public blockchain, on which the GREENEUM transactions take place, and local customizable semi-private blockchains, which are used for energy trading and management services. Access to the GREENEU network is only granted by using its tokens. (Greeneum, 2017) | GREENEUM charges a validation fees on every transaction on the platform. (Greeneum, 2017) |
| 9 | Grid+ | Developing and launching a blockchain-based energy retail business. | 1. Energy consumers<br>2. Utilities (Renaudin, 2017a) | Energy consumers are benefitting from cheaper energy prices and can potentially participate in energy arbitrage via the Grid+ user agent. The user agent will be able to buy and sell energy on behalf of the customer and can also manage the load and provide ancillary services (i.e. NEST thermostat or Tesla Powerwall). Payments for electricity are processed in real-time. (Grid+, 2017) | When customer signs up, he gets access to the Grid+ network with a digital wallet on the Ethereum network and a hardware called smart agent. The smart agent is a device that pays for the electricity usage in real time. (Renaudin, 2017b)<br>Grid+ uses two tokens on the platform: BOLT and GRID. Customers deposit US dollars and receive BOLT (1:1) to pay for electricity on the blockchain. One GRID is a call option to buy 500kWh of electricity at wholesale price on the platform. GRIDs were issued during the ICO. (Grid+, 2017)<br>The user agent will support in balancing the load by controlling customers' smart devices (i.e. NEST thermostat or Tesla charger) | In the short-term Grid+ aims for two main revenue streams. First, it collects the proceeds of its electricity retail business. Grid+ is buying electricity on the wholesale market and sells it to its customers with a 20% mark-up. Grid+ collects the distribution fee as well. Second, the company plans to license its software and hardware to other utilities.<br>The Smart Agent, which customers are required to use, will cost min. $50. Also, Grid+ completely removes bad debt expenses as customers are required to use the deposit model and consequently reduces counterparty risk. (Grid+, 2017; Renaudin, 2017b) |
| 10 | GrünStromJeton, Germany | Ensuring the procurement of green energy. | Energy consumers | Energy consumers can track the share of green power compared to grey power by receiving GrünStromJeton tokens for the procured energy from RES. This increases the transparency for consumers. As green and grey power are basically "mixed" in the grid, but consumers with green power purchasing contracts, which have a built in mark up on green power, would technically overpay as mixed power comes out of the outlet. The tokens could be used to trade and exchange as cryptocurrency. (blog.stromhaltig, n.d.) | GrünStromJeton is running on the Ethereum blockchain and serves as a software solution for the verification of green energy consumption. The actual share and amount of green power is calculated by a green power index in real-time based on the zip code and the measured meter data. The tokens are issued as irrevocable verification of the actually procured green power. The core application can be used without specific devices; a browser to register the meter reading. The smart contract issues tokens as soon as two readings are available. Though it would also be possible to delegate the reading to automate-meter-reading if the meter operator is participating. (blog.stromhaltig, n.d.; Stromhaltig.de, 2013) | GrünStromJetons is an open source project. Users would only need to micro transaction costs for the provided computing power by miners on the blockchain. (blog.stromhaltig, n.d.) |

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| 11 | Jouliette, Netherlands | Empowering to share locally produced renewable energy. (Alliander & Spectral, 2017b) Private, regional, not publicly accessible | Local energy producers and consumers. | Community members are able to exchange renewable energy on the community smart-grid. Users get insights their real-time energy consumption thanks to a community wide power-flow map as well as individualized data visualizations. Community members have the chance to be part of a bottom-up energy transition. (Ross, 2017b) | The energy transaction platform Jouliette running on a blockchain covers the community's private smart grid and is enabled by tokens called Jouliette. With this token the community members can make P2P transactions. The application incorporates machine-learning forecasting systems and features a real-time power-flow map. Jouliette is able to integrate intra-community activities such as car sharing and local time banking. The system developer Spectral is delivering the blockchain software as well as hardware for metering and data collection. (Alliander & Spectral, 2017a; Spectral, 2017) | No information available. |
| 12 | MyBit | Enabling "the crowdfunding of revenue generating machines (IoT Assets)" (MyBit, 2017) global | Private investors | Investors can share ownership of solar panels by crowdfunding. As a return, investors share profits from surplus energy production that is being sold back to the grid or on the P2P market. To incentivize investors, MyBit consequently distributes revenues/profits real-time. (MyBit, 2017) | MyBit wants to set up a platform which allows to commoditize decentral energy infrastructure by crowdfunding. It plans to do so on the Ethereum blockchain on which smart contracts are implemented. This way real-time profit distributions can be enabled as well as ownership secured. The central payment method on the platform will be MyBit Tokens. (MyBit, 2017) | MyBit collects a network fee of 1% on all transactions on its platform. This is then "distributed to token holders based in their percent stake" from total installed solar PV systems. |
| 13 | NRGcoin | Incentivizing production and consumption of renewable energy. (NRGcoin, n.d.) | Energy producers and consumers. | An energy producer is rewarded with 1 NRGcoin, a cryptocurrency, for injecting 1 kWh of electricity. This "conversion rate" is fixed. Therefore it should incentivize the deployment RES independent from subsidies. (NRGcoin, n.d.) | NRGcoin is implemented on the Ethereum blockchain and uses smart contracts to regulate the creation of NRGcoins once electricity is injected into the grid by the energy producers. On the same time, the NRGcoin can replace green certificates as one NRGcoin stands mandatorily for renewable energies. To participate in the network, participants are required to create an online wallet for NRGcoin. (NRGcoin, n.d.) | The concept of NRGcoin "can be deployed and integrated in different ways, offering a variety of revenue streams for differente market players". (NRGcoin, n.d.) There is no information available with regard to how the developers of NRGcoin want to monetize the concept if it is going to be implemented by a market player. |
| 14 | Pilot project by TenneT TSO and sonnen GmbH | Stabilizing the power grid with home storage or EV loading stations. (TenneT, 2017) | Private households. | Private households with storage battery can profit for offering their storage capacity which exceeds their usage on the energy storage network; thus making the battery usage more profitable on an individual level. (TenneT & sonnen GmbH, 2017) | The German TSO TenneT and storage battery manufacturer sonnen are collaborating on a pilot project making a blockchain-based energy storage network to stabilize the grid. The home storage systems are interconnected and their charging management is adjusted according to the grid situation. This way the "linked battery storage devices can absorb or emit any excess power in a matter of seconds where required. It thus contributes to reducing transport bottlenecks in the grid." (TenneT, 2017) The verification and documentation process of these devices is running on a blockchain developed by IBM. The blockchain has only restricted access and guarantees privacy. (sonnen GmbH, 2017) | No information available. |

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| 15 | Power Ledger, Australia | Develop a trustless, transparent, interoperable energy trading platform. (Power Ledger, 2017b) | Commercial and private energy producers and consumers. | On the one hand, residential and commercial businesses can benefit from installing roof-top PV and selling it to local consumers rather than getting the retail price. They can decide to whom they "sell their surplus energy and at what price". On the other hand, consumers profit from "clean, low-cost energy directly from their neighbours". (Power Ledger, 2017a) | Two tokens are utilized by Power Ledger: POWR and Sparkz. POWR can be purchased on cryptocurrency exchanges. They are required to participate on the platform. Further, POWR tokens serve as a reward for prosumers generating (favouring RES) and consumers purchasing electricity on the platform. Sparkz are purchased via fiat currencies. One Sparkz equals one unit of electricity and serves as payment for electricity. POWR can be exchanged for Sparkz, but can also be used directly in P2P trading. Accordingly, Power Ledger makes use of a hybrid public Ethereum and consortium blockchain. The first one is used for the POWR token processes, while on the latter is the core layer and incorporates the processes necessary for P2P trading such as meter readings, Sparkz management and payments (Power Ledger, 2017b; Rusitschka, 2017) | Power Ledger plans to gain two revenue streams. First, it charges a fee on all P2P transactions. A part of that fee goes towards POWR tokens for the rewards program. The remaining part of the fee covers the operating costs of Power Ledger's Ecosystem. Second, Power Ledger will license its P2P trading solution to retailers. (Power Ledger, 2017) |
| 16 | Prosume | Enabling the exchange of energy at a cheaper price and maximizing the use of RES. (Prosume, 2017a) | Utilities, grid-operators, system integrators and communities. (Prosume, 2017b) | The energy trading platform addresses consumer's flexibility to choose the energy source, independent producers and individual prosumers to achieve a better price. System operators can benefit from physical traceability and forecasted production of RES and thereby lower grid maintenance costs. (Prosume, 2017b) | Prosume is a platform that connects independent producers, consumers and utility companies. It integrates power-plant and grid management and serves as an ESCO. The participants get access to the P2P energy trading platform that includes a monitoring system. The platform allows to trade electricity as well as gas. Producers and consumers set their bid and energy price. The settlement will be done by trading algorithms and smart contracts. Whereby, the price range will be predetermined by local regulators, system operators and utilities. To access the platform and trade energy, tokens are used. Prosume platforms can be realized and implemented on a community, regional or global level. (Prosume, 2017b) | No information available. |
| 17 | SolarCoin | "Incentivizing global solar electricity generation". (SolarCoin, n.d.-a) | Solar PV owners. | Solar PV owners receive 1 SolarCoin by generating one MWh of electricity. The SolarCoins can be redeemed for goods and services from participating merchants or exchanged for fiat or cryptocurrencies on online exchanges. This should incentivize the global solar electricity generation as it is not limited geographically. Moreover, this revenue stream on top of regular feed-in-tariffs or net metering regimes reduces the payback time for solar installation (SolarCoin, n.d.-b) | SolarCoins run on a public blockchain similar to Bitcoin, with the distinction that the transactions are verified by proof of solar energy generation and proof-of-stake. The stakers who run the software to maintain the blockchain receive an interest rate of 2% for their effort. SolarCoins are capped at 97.5 Billion SolarCoins representing 97'500 TWh.To participate on the SolarCoin blockchain energy producers are required to create a SolarCoin wallet. (SolarCoin, n.d.-a) | SolarCoin is run by volunteers as an open community project. The volunteers are organized within the SolarCoin Foundation. (SolarCoin, n.d.-b) |

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| 18 | SolarIoT | Pooling solar project funding and building sites. | Private investors and property owners | There are three offerings to individuals. First, they can invest into solar projects. Second, they can offer land or building sites to have solar PV installed. Third, individuals with installed PV can sell their excess energy on the marketplace. (SolarIoT, 2017) | SolarIoT wants to create an investment platform on the Ethereum blockchain. Energy trading takes place "through the token to buy kWh credits at a price". Individuals would still need to submit and negotiate solar PV projects with a contractor, but can then publish the project on the platform and hence open it for investments. The initial funding is then used to pay for the contractor. The generated energy is then sold to distribute profits among investors and property owners. The payment transactions are enabled by tokens. (SolarIoT, 2017) | No information available. |
| 19 | The Sun Exchange | A solar panel sharing economy. (The Sun Exchange, 2017b) | Private investors, community roof owners in South Africa. (The Sun Exchange, 2017a) | Investors can purchase solar cells as part of a crowdsale through The Sun Exchange. After implementation of the solar PV, investors earn a real-time rental income per kWh consumed. (The Sun Exchange, 2017b) Community roof owners usually are able to reduce their electricity costs; for instance Knysna Elephant Park could cut its energy bill by 10% by having funded over 13'000 solar cells, which are now maintained for a minimum period of 20 years. (Jackson, 2017) | The Sun Exchange operates a blockchain-based payment system for facilitating the funding and rental income transactions for the solar PV projects. The payments can be made via Bitcoin or South Africa Rand. The organization acts as a service provider to validate the solar projects commercially and technically, markets them as investment opportunities and arranges the lease agreement. Though it doesn't have itself stakes in the PV assets and isn't installing the PV systems. (The Sun Exchange, n.d.) | The Sun Exchange receives a fee of 5 -25% of every successfully funded solar project and an annuity of 2.5% for the loan period of every project. (The Sun Exchange, n.d.) |
| 20 | TransActive Grid, USA | P2P energy trading market on a microgrid | Energy consumers | Energy consumers can choose where to buy renewable energy from: the local microgrid or the regional power provider. Also, consumers can decide how much they want to spend on the energy source per day. In this sense, they can express their personal preferences towards maximizing return or benefitting the community. (Microgrid News, 2016) | Prosumers have smart meters which register surplus solar energy and create energy credits (meaning the energy is tokenized). These credits are then traded in the local microgrid energy market based on smart contracts. The P2P market runs on Ethereum and is set up on top of the existing infrastructure. The price is determined by supply and demand in the P2P market. However, there is no digital currency to make payments on the blockchain. Utility companies receive a transaction and maintenance fee. (Appelbaum, 2017; LO3 Energy, n.d.)<br>TransActive Grid builds its own hardware (i.e. meter) and software. The company is a joint venture by LO3 Energy and ConsenSys. Among the partners is also Siemens. | Pay a service charge / transaction fee. |
| 21 | Wattcoin | | Energy producers, consumers and utilities. | The Wattcoin platform offers several functionalities to utilities. First, it lowers operational costs thanks to simplified billing processes. (Wattcoin Labs, n.d.-b) Second, real-time energy efficiency reward programs can be implemented as a way of demand response to reduce peak load. (Wattcoin Labs, n.d.-a) | No information available. | Wattcoin is operating as a platform-as-a-service and charges an annual contract fee and revenue sharing contract options. |

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| 22 | WePower | Enabling green energy project financing and green energy investment and trade. (WePower Network, 2017a) Global | Investors, energy producers and consumers. | Energy consumers benefit from lower energy prices than from conventional markets. Consumers are guaranteed to buy green energy and get more transparency. Investors of any size can participate in the growth and development of renewable energy projects financed through the WePower platform. Due to a simplified investment process with lower administrative costs, investors and project developers can expect a higher return on equity. (WePower Network, 2017b) | WePower plans first to work directly with large-scale energy producers. Later, small-scale energy producers should be able sell their excess power on WePower's blockchain-based platform. It tokenizes the generated energy and makes it tradeable on the platform (1 token = 1 kWh). Hence, smart contracts are employed. WePower is partnering with a transmission operator and legally acts itself as an independent energy supplier and "operating under established regulation and relationships between (DSO/ TSO) and fair use of infrastructure". So, the platform is connected to the grid, the local energy exchange and to consumers, and will receive energy production and consumption data. Hence, WePower is buying and selling energy from the wholesale market.<br>Energy producers who want to finance a new project through the platform, sell part of the future energy on the platform in form of smart contracts for each token to the investors. The energy has to be delivered at a specific time. The smart contracts serve as power purchase agreement. (WePower Network, 2017b) | WePower states that "renewable energy producers using WePower platform will be obliged to donate at least 0.9% of all green energy connected to WePower and to be produced in the future". This energy will be tokenized and then distributed between token holders based on the token amount each participant holds. WePower keeps 30% of the tokens as its main revenue stream; 50% go to the initial token sale contributors, and 10% each go to "community and users growth" as well as to "future stakeholders". The token holders can either trade or sell the tokens for energy again. (WePower Network, 2017b) |

# E) Analysis of business models according to identified categories and characteristics

*Table 12: Business models according to identified categories and characteristics.*

| # | Case | Target customer | Value proposition | Value chain | Value capture | Business Model Type |
|---|---|---|---|---|---|---|
| 1 | Bovlabs, Switzerland, USA, India | **Customer group**<br>- Producers<br>- Consumers<br>- Private investors<br>**Network size**:<br>- Global | **Revenue**<br>- Rent /Roi<br>- Sale of electricity | **Business processes/ops.**<br>- Energy trading platform<br>- Crowdsale/funding<br>**Technology**<br>- Ethereum blockchain | **Revenue sources**<br>- Transaction fee | **P2P energy-trading platform / Crowdsale platform** |
| 2 | Conjoule, Germany | **Customer group**<br>- Solar energy producers<br>- Consumers<br>**Network size**:<br>- Local | **Revenue**<br>- Higher remuneration than feed-in-tariff<br>**Flexibility**<br>- Consumers choose energy mix from local generators | **Business processes/ops.**<br>- platform for customers<br>- Compensation for transmission and distribution<br>**Technology**<br>- Ethereum blockchain<br>**Control & energy network**<br>- Forecasting<br>**Financing**<br>- Corporate venture backed by Innogy Innovation Hub and TEPCO | No information available | **P2P energy-trading platform** |
| 3 | Drift, USA | **Customer group**<br>- Consumers<br>**Network size**:<br>- Regional | **Costs**<br>- Lower electricity prices by paying the wholesale price<br>**Transparency**<br>- No hidden charges<br>**Flexibility**<br>- Contract | **Business processes/ops.**<br>- Buying of energy from network of independent energy generators<br>- Selling energy to consumers<br>- Compensation for transmission and distribution<br>- High-frequency trading<br>**Technology**<br>- Distributed ledger instead of blockchain<br>**Control & energy network**<br>- Forecasting<br>**Financing**<br>- Venture capital | **Revenue sources**<br>- Weekly subscription fee | **Retailer** |
| 4 | Electron, United Kingdom | **Customer group**<br>- System operators<br>- Consumers<br>**Network size**:<br>- Regional | **Revenue**<br>- Remuneration for adjusting energy consumption | **Business processes/ops.**<br>- Demand side response trading platform<br>**Control & energy network**<br>- Grid stabilization and balancing<br>**Financing**<br>- Venture capital | No information available | **Flexibility-trading platform** |

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| 5 | Enbloc, USA | **Customer group**<br>- Energy prosumers<br>- Consumers<br>**Network size**: | **Revenue**<br>- Sale of surplus energy<br>**Costs**<br>- Lower electricity prices<br>**Transparency**<br>- Consumers can choose local, clean energy | **Business processes/ops.**<br>- Energy trading platform<br>- Smart metering<br>**Technology**<br>- Private blockchain | **Revenue sources**<br>- Transaction fee | **P2P energy-trading platform** |
| 6 | Enerchain, Europe | **Customer group**<br>- Producers<br>- Utility companies<br>- Retailer<br>**Network size**:<br>- Regional | **Costs**<br>- Reducing administrative costs | **Business processes/ops.**<br>- OTC wholesale energy trading platform<br>**Technology**<br>- Tendermint blockchain<br>**Control & energy network**<br>- Integrating energy trading and risk management system<br>**Financing**<br>- Corporate project | No information available | **OTC trading platform** |
| 7 | Energi Mine, UK | **Customer group**<br>- Producers<br>- Consumers<br>**Network size**:<br>- Global | **Costs**<br>- Lower electricity prices | **Business processes/ops.**<br>- Energy trading platform<br>- Battery trading exchange<br>- Tokenization<br>**Technology**<br>- Artificial intelligence<br>**Financing**<br>- Initial token offering | No information available | **P2P energy-trading platform** |
| 8 | GREENEUM | **Customer group**<br>- Producers<br>- Consumers<br>- Prosumers<br>- Utility companies<br>- System operators<br>**Network size**:<br>- Local<br>- Global | **Revenue**<br>- Sale of RECs<br>- Higher remuneration for energy producers<br>- Utility companies receive distribution and service<br>**Costs**<br>- Lower administrative costs | **Business processes/ops.**<br>- Separate platforms for energy trading, forecasting and monetization<br>- Tokenization<br>**Technology**<br>- Software: artificial intelligence, Ethereum blockchain (public and semi-private)<br>**Control & energy network**<br>- Energy management services<br>**Financing**<br>- Initial token offering | **Revenue sources**<br>- Transaction fee | **P2P energy-trading platform** |

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| 9 | Grid+ | **Customer group**<br>- Consumers<br>- Utility companies / Retailers<br>**Network size**:<br>- Global | **Costs**<br>- Lower electricity prices for consumers<br>- Lower administrative costs for utility companies / retailers<br>**Transparency**<br>- Energy bill components | **Business processes/ops.**<br>- Buying electricity on wholesale market<br>- Selling energy to consumers<br>- Tokenization<br>- Compensation for transmission and distribution<br>**Technology**<br>- Hardware: smart agent which automates billing and controls customers smart devices<br>- Software: Ethereum blockchain<br>**Control & energy network**<br>- Ancillary services (balancing the load)<br>**Financing**<br>- Initial coin offering | **Revenue sources**<br>- Transaction fee 20%<br>- min. 50$ for smart agent | **Retailer** |
| 10 | GrünStromJeton, Germany | **Customer group**<br>- Prosumers<br>- Consumers<br>**Network size**:<br>- Regional | **Transparency**<br>- Procured energy mix | **Business processes/ops.**<br>- Tokenization (based on calculation of the actual share and amount of green power using a green power index, the zip code and meter data)<br>**Technology**<br>- Ethereum blockchain<br>**Financing**<br>- Corporate partnership / project | **Revenue sources**<br>- Open source | **Transparency regarding procured energy mix** |
| 11 | Jouliette, Netherlands | **Customer group**<br>- Prosumers<br>- Consumers<br>**Network size**:<br>- Local | **Revenue**<br>- Sale of surplus energy<br>**Transparency**<br>- Real-time energy consumption | **Business processes/ops.**<br>- Energy trading platform<br>- Tokenization<br>**Technology**<br>- Software: artificial intelligence, in-house blockchain<br>- Hardware: smart meter<br>**Financing**<br>- Corporate partnership / project | No information available | **P2P energy-trading platform** |
| 12 | MyBit | **Customer group**<br>- Private investors<br>**Network size**:<br>- Global | **Revenue**<br>- Rent / RoI | **Business processes/ops.**<br>- Crowdfunding platform<br>- Tokenization<br>- Real-time profit distributions<br>**Technology**<br>- Ethereum blockchain | **Revenue sources**<br>- Transaction fee | **Crowdsale platform** |

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| 13 | NRGcoin | **Customer group**<br>- Producers<br>- Prosumers<br>- Consumers | **Revenue**<br>- Sale of RECs<br>**Transparency**<br>- Produced green energy | **Business processes/ops.**<br>- Tokenization<br>- Creation of NRGcoins once electricity is injected into the grid by the energy producers, resembling RECs<br>**Technology**<br>- Ethereum blockchain<br>**Financing**<br>- Industry-academia project | No information available | **Renewable energy certificates** |
| 14 | Pilot project by TenneT TSO and sonnen GmbH | **Customer group**<br>- Prosumers<br>- Consumers<br>**Network size**:<br>- Regional | **Revenue**<br>- Offering storage capacity<br>**Costs**<br>- Lowering electricity costs | **Business processes/ops.**<br>- Energy storage network<br>**Technology**<br>- Private blockchain developed by IBM<br>**Control & energy network**<br>- Grid stabilization and balancing<br>**Financing**<br>- Corporate partnership / project | No information available | **Flexibility-trading platform** |
| 15 | Power Ledger, Australia | **Customer group**<br>- Producers<br>- Prosumers<br>- Consumers<br>- Utility companies / retailers<br>**Network size**:<br>- Global | **Revenue**<br>- Sale of surplus electricity<br>**Costs**<br>- Lowering electricity costs | **Business processes/ops.**<br>- Energy trading platform<br>- Tokenization<br>**Technology**<br>- Hybrid public Ethereum blockchain and consortium blockchain<br>**Financing**<br>- Initial token offering | **Revenue sources**<br>- Transaction fee<br>- Licensing | **P2P energy-trading platform** |
| 16 | Prosume | **Customer group**<br>- Utility companies / retailer<br>- System operators<br>**Network size**:<br>- Local<br>- Regional<br>- Global | **Costs**<br>- Lower administrative costs | **Business processes/ops.**<br>- Energy (electricity and gas) trading platform<br>- Tokenization<br>**Technology**<br>- Ethereum blockchain<br>**Control & energy network**<br>- Forecasting<br>- Power plant and grid management<br>**Financing**<br>- Initial coin offering | No information available | **P2P energy-trading platform** |
| 17 | SolarCoin | **Customer group**<br>- Producers<br>- Prosumers<br>- Miners<br>**Network size**:<br>- Global | **Revenue**<br>- Miners receive a rent of 2% for their effort<br>- REC<br>**Transparency**<br>- Produced green energy | **Business processes/ops.**<br>- Tokenization<br>**Technology**<br>- Public blockchain similar to Bitcoin<br>**Financing**<br>- Open community project | **Revenue sources**<br>- Open source | **Renewable energy certificates** |

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| 18 | SolarIoT | **Customer group**<br>- Private investors<br>- Property owners<br>**Network size**:<br>- Global | **Revenue**<br>- Rent through investing or offering land or building sites for solar PV developments<br>- Sale of surplus electricity | **Business processes/ops.**<br>- Crowdfunding platform<br>- Energy trading platform<br>- Tokenization<br>**Technology**<br>- Ethereum blockchain<br>**Financing**<br>- Start-up without funds | **Revenue sources**<br>- Open source | **Crowdsale platform** |
| 19 | The Sun Exchange | **Customer group**<br>- Private investors<br>- Property owners<br>**Network size**:<br>- Global | **Revenue**<br>- Rent<br>- Sale of surplus electricity<br>**Costs**<br>- Lower electricity costs | **Business processes/ops.**<br>- Crowd-sale platform<br>- Service provider for crowd-sale, marketing, arrangement of leasing agreement and distributing profits<br>**Technology**<br>- Blockchain<br>**Financing**<br>- Venture capital | **Revenue sources**<br>- Commission fee<br>- Annuity | **Crowdsale platform** |
| 20 | TransActive Grid, USA | **Customer group**<br>- Prosumers<br>- Consumers<br>**Network size**:<br>- Local | **Revenue**<br>- Sale of surplus electricity<br>**Flexibility**<br>- Energy mix and price | **Business processes/ops.**<br>- Tokenization<br>**Technology**<br>- Software: Ethereum blockchain<br>- Hardware: Smart meters<br>**Financing**<br>- Corporate partnership / projects | **Revenue sources**<br>- Transaction fee | **P2P energy-trading platform** |
| 21 | Wattcoin | **Customer group**<br>- Utility companies / retailers<br>**Network size**:<br>- Local<br>- Regional<br>- Global | **Costs**<br>- Lower administrative costs | **Business processes/ops.**<br>- Platform-as-a-service<br>**Technology**<br>- Blockchain<br>**Control & energy network**<br>- Demand response<br>**Financing**<br>- Start-up without funding | **Revenue sources**<br>- Licensing<br>- Transaction fees | **P2P energy-trading platform** |
| 22 | WePower | **Customer group**<br>- Private investors<br>- Producers<br>- Prosumers<br>- Consumers<br>**Network size**:<br>- Global | **Revenue**<br>- Sale of surplus electricity<br>- Rent<br>**Costs**<br>- Lower electricity prices<br>**Transparency**<br>- Procured energy mix | **Business processes/ops.**<br>- Energy trading platform<br>- Tokenization<br>**Technology**<br>-<br>**Financing**<br>- | **Revenue sources**<br>- Transaction fee | **P2P energy-trading platform** |