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Exploring technological transitions: Case study on the implications of the blockchain technology in the development of the Finnish energy sector

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ABSTRACT

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This master's thesis presents a case study on the implications of emerging technologies in systemic transition trajectories. More specifically, an ongoing technological transition, referring to major technological changes in the way societal functions are fulfilled, is explored in the context of the Finnish energy sector, by studying the implications of an emerging technology known as the blockchain in the development of the industry. The blockchain refers to a digital technology platform for facilitating decentralized transactions, which has recently introduced a potent but disruptive value proposition on the arrangement of systemic structures and business activities. By integrating contemporary literature on technology, innovation, business ecosystems, and managerial cognition, a theoretical framework is developed for analysing the components and mechanisms through which emerging technologies interact with their surrounding environments. As a conclusion, this study identifies that emerging technologies present re-configurative implications in multiple dimensions of systemic structures, whereas the blockchain technology proposes a fundamental change to the system architectures of the Finnish energy sector, thus stimulating a transformation of the dominant resource configuration from static and linear collaboration models into dynamic and interactive transaction enablement.

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Tämä Pro Gradu tutkii tapaustutkimuksen keinoin uusien teknologioiden vaikutuksia systeemisten liiketoimintaympäristöjen kehityksessä. Tarkemmin ottaen, meneillään olevaa teknologista siirtymää, jolla viitataan merkittäviin teknologisiin muutoksiin yhteiskunnan toimintojen toteuttamisessa, tutkitaan Suomen energiasektorin kontekstissa tarkastelemalla lohkoketjuteknologian vaikutuksia toimialan kehityksessä. Lohkoketjulla tarkoitetaan teknologia-alustaa joka mahdollistaa hajautettujen transaktioiden toteuttamisen digitaalisessa ympäristössä, mikä puolestaan on hiljattain nostanut esille voimakkaan ja disruptiivisen näkemyksen järjestelmä-arkkitehtuurien ja liiketoiminnan rakenteiden suunnittelusta. Tämä tutkielma yhdistää teknologiaan, innovaatioihin, liiketoiminta-ekosysteemeihin ja liikkeenjohdon kognitioon pohjautuvaa kirjallisuutta teoreettisen viitekehyksen luomiseksi, jonka avulla voidaan hahmottaa uuden teknologian ja tämän ympäristön välistä vuorovaikutusta määrittäviä komponentteja ja mekanismeja. Tässä tutkimuksessa todetaan, että uudet teknologiat konfiguroivat ympäristöjään useassa ulottuvuudessa. Lohkoteknologia ennakoi perustavanlaatuista muutosta Suomen energiasektorin järjestelmä -, ja liiketoiminta-arkkitehtuureihin, mikä puolestaan stimuloi toimialaa hallitsevien resurssikokoonpanojen muutosta staattisista ja lineaarisista yhteistyömalleista kohti dynaamisia ja vuorovaikutteisia transaktiomalleja.

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The academic quality fostered by the LUT School of Business and Management has left me with the right tools for seeking knowledge and success where ever I may find myself in. For this, I want to thank all the exceptional professionals working at LUT. Indeed, this is not the end, but rather a beginning for a life-long adventure in continuous learning and improvement across endless fields of innovation.

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LIST OF KEY CONCEPTS

Ecosystem:	An open social system of organizational fields that consist of directly, indirectly, and less formally interdependent actors, technologies, and institutions.
Technology:	Multi-dimensional construct of physical objects or artefacts, activities or processes and the knowledge needed to develop and apply these. Technology describes the transformation processes of converting inputs into outputs.
Institutions:	Enable value creation and govern the patterns of interaction within the technological frameworks. Institutions consist of social rules, norms, values, meanings, beliefs, regulators, policymakers, and interest groups.
Technological transition:	A major technological change in the way societal functions are fulfilled.
Blockchain:	A digital management technology platform for immutable decentralized databases, that facilitates trust, security, and automation in complex networks of systems and actors by leveraging cryptography and distributed consensus mechanisms.
P2P-transactions:	Parties engaging in direct transactions or contractual agreements with each other, in the absence of a mediator or a trusted third party that facilitates the activity by providing authentication and guarantee services.
Demand response:	Temporal adjustment of end-user consumption or production of electricity based on incentives.
Smart grid:	An extensive energy service platform that consists of physical transfer, production, and storage of electricity, decentralized resources, demand response, and smart grid applications, and connects the physical grid into wholesale and retail markets.

LIST OF ABBREVIATIONS

AI: Artificial intelligence
AMR: Automatic meter reading
API: Application programming interface
BEV: Battery electric vehicle
BFT: Byzantine Fault Tolerant
BLE: Bluetooth low energy
CHP: Combined heat and power
DDI: Digital Disruption of Industry research project
DSO: Distribution system operator
EA: The Energy Authority
EU: European Union
EV: Electric vehicle
ICT: Information and communications technology
IoT: Internet of Things
IT: Information technology
NFC: Near field communication
P2P: Peer-to-peer
PESTEL: Political, economic, social, technological, environmental, legal
PHEV: Plug-in-hybrid vehicle
POA: Proof of activity
POS: Proof of stake
POW: Proof of work
PV: Photovoltaic
R&D: Research and development
RFID: Radio frequency identification
SNA: Social network analysis
TEM: Ministry of Economic Affairs and Employment
TSO: Transmission system operator
TT: Technological transition
TX: Transaction
vRE: Variable renewable energy

1. Introduction

This master's thesis adopts a technological perspective for studying industry transformations. This phenomenon is elaborated through a case study on a novel innovation known as *the blockchain*, in the context of the *Finnish energy sector*. The blockchain refers to a digital technology platform for facilitating decentralized transactions, whereas the Finnish energy sector is identified as an interesting environment for a study due to its unique position under pressure for a technological transition. Based on the existing academic literature, a theoretical framework is developed for exploring the implications of emerging technologies in technological transition trajectories. This framework is applied to the case study context in order to study its applicability and contribution to both academia and business management.

This study is a part of a research project facilitated by Digital Disruption of Industry (DDI) consortium, with an *"aim to model the digital disruption and to strive for active measures for influencing the direction and speed of the change"* (DDI, 2016a). The consortium consists of many Finnish research organizations such as Aalto University, ETLA, Lappeenranta University of Technology, VTT Technical Research Center of Finland and University of Turku (DDI, 2016b). This study contributes to the DDI project in the category of Future Foresights, developing research to *"study the potential progress of the ecosystems and their crossovers using multiple methods such as scenarios, roadmaps, techno-economical modelling and simulation, and impact studies"* (DDI, 2016a).

1.1. Background of the study

Energy brings our modern society to life. It is the enabler of development and the backbone of our infrastructure. Our dependency on energy, and the consequences of a sudden failure in energy access can be observed through numerous case examples. For example, in 2012 hurricane Sandy caused an estimated financial damage of 100 billion dollars in the United States (Kunz et al. 2013) and caused 8,5 million people to lose power (USA Department of Energy, 2013) and severely damaged the petroleum infrastructure (USA Department of Energy, 2012). This catastrophic power-out escalated to interrupt critical operations in many other industries, while also setting human lives at risk (Haraguchi & Kim, 2016). Yet, the estimated likelihood of such extreme weather events has more than doubled due to global warming (Chang et al. 2012), which is well known to be accelerated by the current status quo in global energy production and consumption behaviour.

Fortunately, progress is being made on a path towards sustainable future. This transition is mainly driven by diminishment of our primary sources of fossil fuels, the growing importance of climate change mitigation and increase in global energy demand due to the growth of population and industrialization of developing countries (Kopsakangas-Savolainen & Svento, 2013). According to statistics, the rate of development in the renewable energy sector discloses rather optimistic figures. For example, the global cumulative installed capacity of wind power has grown 152% during the last ten years (GWEC, 2015). The growth rate has been even higher in photovoltaics (PV), disclosing over 190% growth from 2005 figures (IEA, 2016). At the same time, zero-emission energy is projected to account for 60% of the global installed capacity by 2040 (BNEF, 2016). Importantly, technological development, not just in energy production methods itself, but also in complementary innovations such as energy storage, is emphasized as an important catalyst for making variable renewable energy (vRE) a viable and competitive alternative for the traditional energy production (Hirth, 2012; Fingrid, 2017a). It is clear, that the structure of the global energy production going through significant changes.

Despite of all its benefits, the development trajectory of decarbonizing the energy system across multiple domains, such as heat, waste, and transportation also incorporates negative externalities that must be accounted for. As we compensate for fossil fuels, the demand for electricity increases dramatically, while our society becomes increasingly intolerant towards failures in the electrical network (Fingrid, 2017a). In the future, this deficit will be filled by increasing the share of renewable energy production (Sonnenschein et al. 2015; Sorri et al. 2016; Almpanopoulou et al. 2017). However, due to their natural dependency on weather conditions, renewables are fundamentally characterized by uncertainty, variability and location-specificity (Hirth, 2012). This causes the impact of energy intermittency to grow its presence in the future energy systems. A logical approach to solve these issues and hindrances suggest for developing the level of decentralization of the energy system, while dynamically allocating resources across the energy system to flatten out demand and supply peaks (Sonnenschein et al. 2015). However, such decentralized system structure carries an overall performance cost by increasing complexity and demand for coordination (Galbraith, 1973), indicating a need for efficient automation, communication, and control technologies.

Digitalization is an antecedent for enabling efficient and real-time market interaction in the energy sector, and providing the tools for managing the developing complexity of the system network (Fingrid, 2017a). It has been argued that we are currently living in the aftermath of a collaborative revolution, built from platform ecosystems that are powered by social, mobile, and cloud technologies, combined with sophisticated analytics (Korhonen, 2016). These platform ecosystems represent digital platforms and technologies, consisting of systems that enable and facilitate connectivity between a myriad of market actors (Aarikka-Stenroos & Ritala, 2017; Seppälä et al. 2015; Gawer & Cusumano, 2014). While an ever-increasing number of devices and objects are being connected to the internet on a daily basis, modern market actors have become accustomed to instantaneous interaction, and availability of information. This development trajectory is also becoming increasingly prevalent in the energy sector. In attempts to seize the emerging opportunities, energy companies are rushing towards developing digital energy business models and technologies. For example, smart grids and demand response systems have been recently become subjects of interest in the industry (Fingrid, 2017a). This is well illustrated in research conducted by consultants at Navigant (2016), who conceptualize the future energy system as a transactive cloud network consisting of a myriad of interconnected smart objects and distributed energy production units. The concept of an emerging energy cloud in an example of a platform ecosystem, where market interaction is facilitated by digital technologies that enable enhanced value creation and capture.

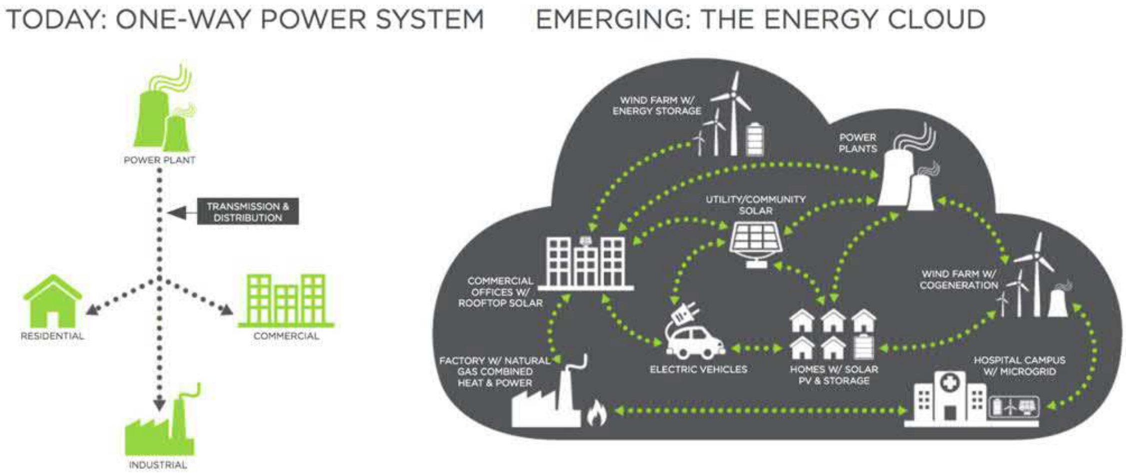

Figure 1. The emerging energy cloud (Navigant, 2016)

Even though the opportunities provided by digital technologies in creating increasingly customer oriented and optimized energy systems have been widely acknowledged, the energy industry seems to lag behind in digitalization. This inertia may be at least partially explained through factors such as long investment cycles, and systemic interdependence on incumbent actors, that create barriers for the industry renewal (Ritala et al. 2017). The current energy market cannot be considered as collaborative, while most consumers adapt passive roles in an energy system designed as a one-way supply chain (Sorri et al. 2016; Honkapuro, 2017). Indeed, the energy industry has not yet fully witnessed the effects of digital disruption in democratizing markets and enabling collaborative activities. Incentives and innovations are needed for developing a digitalized two-way energy system that promotes sustainable, flexible, and convenient energy consumption (Honkapuro, 2017).

Interestingly, an innovation originally introduced in 2008, nowadays known as *the blockchain* (Nakamoto, 2008), has recently developed a significant amount of interest and momentum across a myriad of industries (Yli-Huumo et al. 2016), and the energy sector is no exception. It is an emerging digital technology platform for decentralized and collaborative data sharing across a network of untrusted participants, that can be used to reach consensus on the validity and the state of the transactions and value between collaborating parties without trusting a central authority, or any particular participant (Weber et al. 2016). In other words, the blockchain technology facilitates systems integration and enables bypassing of intermediaries, thus presenting a new form of organizing in complex system structures, making it an attractive technology for hosting multi-sided and distributed networks.

The potential of the blockchain has been identified through a number of novel use cases and solutions for example in IoT (Dorri et al. 2016), finance (Foroglou & Tsilidou, 2015), and supply chains (Christidis & Devetsikiotis, 2016). In the context of the energy sector the technological development of the blockchain drives an emergence of decentralized entities that autonomously produce and allocate energy among themselves (Mattila et al. 2016a). Due to its diverse applicability, development of the core technology itself occurs across multiple industries. This builds interesting implications for business opportunities and synergies in the energy sector, as through its organization-spanning properties, the blockchain technology may facilitate connectivity between industries. Yet, the technology currently exists in its early stages of development, creating significant difficulties for market actors to conceptualize its usability and potential in industry transformations.

1.2. Research gaps and objectives

Research identifies industry transformations as complex processes that unfold along spatial and temporal dimensions, and are constrained by both internal and external development barriers (Geels, 2002; Ansari et al. 2016; Aarikka-Stenroos & Ritala, 2017; Kant, 2017). For example, Ritala et al. (2017) provide evidence on transformational inertia resulting from systemic interdependence, that culminates into difficulties in the establishment of shared vision, leadership, and joint value creation. Yet, knowledge on overcoming such challenges is considered as fuzzy and nascent field of research that requires further attention and detail in the enabling factors of systemic transformations (Hannah, 2015; Hellström et al. 2015; Overholm, 2015; Gustafsson et al. 2016; Dattée et al. 2017).

Contemporary literature identifies digitalization as one of the key drivers and enablers of industry transformations. The emergence of digital technologies has significantly reduced information asymmetries and friction between market actors, by enhancing transparency and efficiency at which resources are exchanged, combined, and integrated. Such development trajectory has expanded the range of resources organizations can access, and the needs they can address. (Amit & Han, 2017) Consequently, an ecosystem perspective that focuses on increased connectivity, interdependence, and co-evolution of actors, technologies, and institutions, has become essential in understanding the development of modern industries embedded in complex business networks (Aarikka-Stenroos & Ritala, 2017).

A vast stream of literature has adopted a system-based view in elaborating how systemic transformations have occurred (e.g. Christensen, 1997; Garud et al. 2002; Li, 2009; Zott & Amit, 2010; Zott et al. 2011; Adner & Kapoor, 2015; Ansari et al. 2016). The system-based view, however, tends to consider the resources of the ecosystem as directly embedded into the focal firm, while ecosystems actually consist of a much broader set of resources, from some of which may be indirectly related to the focal firm, or not currently related at all (Amit & Han, 2017). As such, the literature commonly describes a focal actor that engages in solving issues, establishing rules of the ecosystem, and promoting their own objectives. Furthermore, Dattée et al. (2017) note that ecosystem creation is often considered almost as a linear design process, which is not applicable due to the stochastic behaviour of technologies that may present an unbounded range of potential value propositions. Another common issue is that research data is typically generated only after a disruption has taken place (Nagy et al. 2016). As the rate of digital disruption increases, technological perspective in business management and upfront thinking and deliberate design of systems grow in importance (Korhonen, 2016). Indeed, the longitudinal evidence on the disruptive implications of new technologies in industry structures is irrefutable (Geels, 2002; Geels & Schot, 2007; Cohen et a. 2017). This suggests for the importance of shifting focus towards understanding how emerging technologies bring about profound changes in systemic structures.

This thesis adopts a technological perspective on studying the research gap as identified above, with an objective to understand the implications of emerging technologies in systemic transformation trajectories. Special interest is aimed towards exploring the role of new technology in transforming technological transition pathways. Based on the existing literature, this study develops a theoretical framework for analysing and assessing emerging technologies in their surrounding environments. Due to the high complexity of the phenomenon of interest, abstraction is utilized by defining a limited scope for the study within the boundaries of the theoretical framework. More specifically, a novel innovation known as *the blockchain technology* is studied in the context of *the Finnish energy sector.* Even though the principles of the blockchain were already introduced in 2008 (Nakamoto, 2008), applying the technology to the energy sector is still a novel idea. Due to the low level of understanding on the technology, and its potential range of applications, further research on the blockchain technology and its implications in the development of industries needs to be developed (Christidis & Devetsikiotis, 2016; Hasse et al. 2016; Yli-Huumo et al. 2016).

1.3. Research questions

Building from the previous chapters the blockchain technology is identified as a novel innovation with transformative potential in the existing energy system structure. However, the role of this innovation in the technological development trajectory of the energy sector remains unexplored. Hence, a single main research question is introduced:

1. *What are the implications of the blockchain technology in the development of the Finnish energy sector?*

In order to address the main objective of this research, more general knowledge on the research context needs to be developed. Importantly, it is essential that a profound understanding on the technology and the environment of interest are explicitly formulated. Consequently, two additional sub-questions are implemented:

1.1. How the blockchain technology can be applied in the energy sector?
1.2. What are the challenges for adopting the blockchain technology in the energy sector?

The research questions elaborated in this chapter are further explored within the boundaries defined by the theoretical framework developed in this study (figure 17). More specifically, conclusions are formulated through a qualitative case study constructed from an extensive collection of research data, which is analysed in detail with both inductive and abductive research methods.

1.4. Delimitations

An ecosystem is a complex organizational construct that is often ambiguously conceptualized in literature. Careful articulation must be emphasized when considering ecosystems in a research context. (Ritala & Almpanopoulou, 2017) Thus, delimitations are applied to enable abstraction of the complex research phenomenon and facilitate reliable and valid research outcomes. In the process, some details are lost in exchange for a higher level of comparability.

This study focuses on a specific innovation in a limited context. The scope is defined as *the blockchain technology in the context of the energy sector.* As an abstraction, the energy sector is considered only partially, covering its functions related to electricity. The concept of an ecosystem is used to model the business environment of the energy sector consisting of direct, indirect and loose ties between networks of actors (Aarikka-Stenroos & Ritala, 2017). Moreover, *"the energy ecosystem"* is delimited as the *"ecosystem of electricity",* and further abstracted as an organization with three main functions; *(i) production* -, *(ii) distribution* -, and *(iii) consumption* of energy. These three functions are completed by turning inputs into outputs by utilizing technology (Hatch, 1997, 130) that exists embedded in the institutional environment of the ecosystem that defines the rules associated with the technology (Garud et al. 2002). This study focuses on implications, referring to logical consequences and causalities, between a technology and the components of the energy ecosystem. Moreover, the implications are explored within the theoretical framework developed in this study. In other words, the blockchain technology is studied in the context of the Finnish energy sector in terms of its role in the development of the industry.

1.5. Structure of the study

The first chapter of this study provides an introduction for the research by discussing the backgrounds of the phenomenon of interest, while also specifying the research gaps, objectives and questions. In addition, delimitations are applied in order to specify the scope of analysis. Due to the novelty of the technology in the focus of this study, the second chapter is established to provide an understanding on the technology core, enabling further analysis of the case study. Further on, the third chapter adopts a technological perspective on organizational transformations, in order to induce a theoretical framework for analysing the implications of technology in the process of ecosystem development.

The fourth chapter elaborates the research process applied in the empirical case study presented in this thesis. By analysing the research data, the case context is described in the fifth chapter. The sixth chapter then applies the findings to the theoretical framework by discussing the implications of an emerging technology in the transformation process of ecosystems. Finally, conclusions are presented together with an evaluation of the results of this study in both academic and business context.

2. Blockchain technology, concepts and specifications

This chapter provides a review on the blockchain technology to uncover the properties and development of the innovation. The technology is analysed through its technical functionality, potential and applicability, while also acknowledging the current challenges and limitations in relation to its wide-scale adaptation in business. In-depth understanding of the technology core is essential in order to further analyse and apply its implications in a specific context.

2.1. Definitions

During the recent years, the concept of a blockchain has quickly evolved to become a reference for multiple decentralized functions and processes. This development originates from a paper by Nakamoto (2008), that combines peer-to-peer technologies with cryptography and consensus algorithms, creating an architecture for distributed ledgers and transaction systems. Since then, the innovation has developed to incorporate an ever-developing array of functionalities and use-cases. Hence, the blockchain is used as an umbrella definition for a myriad of distributed system solutions that adapt features as elaborated in this review.

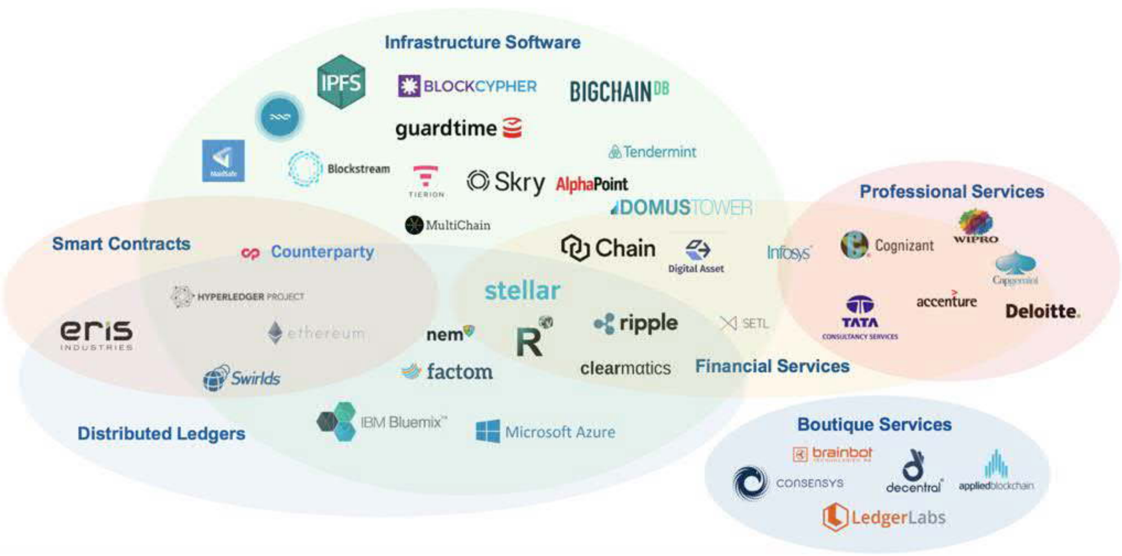

Figure 2. Blockchain application ecosystem (Gartner, 2017a)

By definition, blockchain technology refers to immutable public databases secured by cryptography and a network of peer-to-peer participants (Dorri et al. 2016). Hence, the blockchain is considered as a digital transaction system. In order to clarify the concept, the three main features of blockchain systems are listed in the table 1.

Feature	Description
Decentralized control	No one owns or controls the network
Immutability	Written data is tamper-resistant and forever
Decentralized creation and transfer of assets	No reliance on a central entity

Table 1. The main features of blockchain databases (McConaghy et al. 2016)

The blockchain technology is considered as a platform that constitutes of multiple functions, namely – *blockchain, protocol and currency*, that can be adapted in various configurations, differentiating blockchain systems from one another (Swan, 2015, 1). More specifically, this platform can be considered in terms of layers, namely; hardware -, network -, data/protocol -, processing -, platform -, and application layers – constituting the blockchain technology stack (Mattila, 2016). Each layer presents essential functionalities that can be leveraged differently in various systems.

The blockchain itself is an append-only ledger that stores data, while the protocol determines how transactions (TX) are conducted, whereas the currency represents the tokenization of the transactions (Swan, 2015, 1, 70-71; Anderson et al. 2016; Hasse et al. 2016). The blockchain ledger cumulatively stores the complete transaction history of the entire system, from its inception to the latest entry (Beck et al. 2016). Importantly, these distributed systems diverge from traditional hub-based information networks, as in blockchains, data is not stored in a central database, but distributed to all participants of the network to store the database locally (Mattila & Seppälä, 2015). Therefore, each node has equal and shared access to the database, while running the blockchain on their own systems – hence the term “public ledger”, which refers to a single shared truth (Christidis & Devetsikiotis, 2016). The decentralized peer-to-peer system structure of a blockchain network is described in the figure 3.

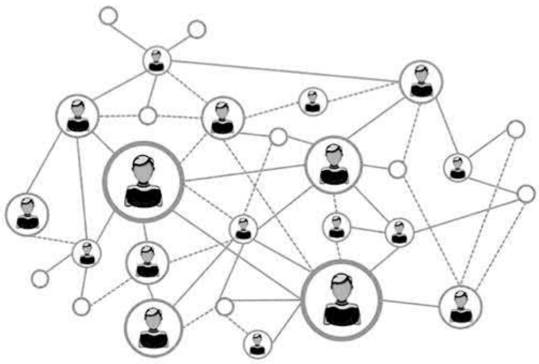

Figure 3. Decentralized network (Zheng et al. 2017)

Blockchain network manages transactions and changes to the database through a system protocol (Swan, 2015, 1). The protocol constitutes of a distributed consensus system, facilitated by cryptography and validation activities performed by the nodes of the network (Tschorsch & Schauermann, 2016). In order to make additions or changes to the blockchain, the data must be validated by the majority of the network nodes by reaching consensus on the content of the blockchain (Yli-Huumo et al. 2016). In blockchain systems, transactions are bundled into units of fixed size, called *“blocks”* which are chronologically stored one after another and linked together through cryptography, hence the name *“blockchain*” (Swan, 2015, 2; Anderson et al. 2016; Christidis & Devetsikiotis, 2016).

On top of the protocols, blockchain transactions are based on currencies, specified in the system (Swan, 2015, 1). Currency in blockchain systems can be almost any symbol of value that can be quantified and transferred in a digital format. Just as in the physical world, digital value is determined through scarcity, trust and competition. In blockchain environment, this is facilitated by the applied protocols that control the creation and distribution mechanisms of currencies (Swan, 2015, 2; Tschorsch & Schauermann, 2016). As the modern blockchain applications have been extended to cover increasingly advanced functionalities beyond financial applications such as the Bitcoin, a more appropriate term would be to consider blockchain currencies as *"tokens"* that in addition to representing currencies, grant access to blockchain applications and act as keys for the execution and tracking of digital transactions (Swan, 2015, 70-71; Hasse et al. 2016).

Overall, the blockchain technology is a concept that suffers from rather ambiguous definitions. Conceptualizing the applicability and purpose of the technology especially in business context is generally considered as rather difficult. As a conclusion, this study develops a modified definition for the blockchain technology:

- *Blockchain technology is a digital management technology platform for immutable decentralized databases, that facilitates trust, security, and automation in complex networks of systems and actors by leveraging cryptography and distributed consensus mechanisms.*

2.2. Motivations for implementing blockchain systems

Even though modern digital technologies are able to meet the communication and data storage requirements of large-scale networks rather effectively, fundamental problems remain with interconnectivity, efficiency, and security of systems. Especially the establishment of trust between stakeholders lingers as a key concern, as in digital environment, transactions and data can be easily copied, modified and falsified (Tschorsch & Schauermann, 2016). For example, sending an e-mail transfers the message to the recipient, but the sender will be able to keep a copy of the transaction. This concept is particularly problematic in the transfer of digital value, as the recipient cannot be certain that the value received has not been copied or altered along the transfer, thus enabling double spending, and rendering the transaction worthless.

Authentication of digital transactions can be easily managed through privately owned services, functioning as trusted middlemen for transaction validation (Yli-Huumo et al. 2016). This system architecture, however, introduces many security risks for example on the centralization of power and the integrity of the third parties taking part in transactions, while from the perspective of transaction cost economics resulting in significant inefficiencies, especially when multiple distrustful entities may be required to participate in common processes or activities (Beck et al. 2016). Yet, significant inertia exists in arranging such collaboration, as organizations are often reluctant to submit into operating within systems controlled by others (Mattila et al. 2016a). Consequently, there is an increasing need for a technology that facilitates complete independence and security of peer-to-peer transactional systems.

The blockchain technology, is expected to drive the next wave of digital disruption by facilitating the development of the next generation of internet interaction systems (Zheng et al. 2017). The most significant benefit of the technology is its design that integrates trust and security into the system itself, enabling its users to completely bypass any third parties in transactional relationships, thus creating advantages in cost and efficiency (Christidis & Devetsikiotis, 2016). Importantly, the blockchain provides a plausible solution for a transition towards multi-sided markets by enabling the distribution of the technology stack, minimizing information asymmetries and encouraging the development of complementarities and the fostering of broader network effects (Mattila et al. 2016b), thus creating novel business opportunities.

2.3. Distributed database

The core of the blockchain technology consists of a distributed database, typically referred to as the blockchain (Christidis & Devetsikiotis, 2016). Users interact with the blockchain via clients installed on nodes that represent computers of various kind (Zheng et al. 2017). Due to the decentralized system structure, nodes can join or leave the network at any time, without disrupting the other nodes and the ongoing processing of transactions (Greenspan, 2015a). The blockchain literally consists of a chain of blocks, as demonstrated in the figure 4. Each block contains a certain amount of data – a number of transactions within a certain period of time, specified in the system protocol (Beck et al. 2016). In this sense, blocks are containers for transactions that consist of identifiable data packages that store parameters and results of function calls (Weber et al. 2016). The blocks are chained together by adding the cryptographic digest of the previous confirmed block, known as the parent, to the new block (Tschorsch & Schauermann, 2016; Zheng et al. 2017). This way, transactions can be validated by following the chain all the way to the *“genesis block”*, containing the initial transactions executed in the system (Christidis & Devetsikiotis, 2016).

The complete blockchain constitutes a public ledger which is distributed throughout the network (Tschorsch & Schauermann, 2016). From the perspective of scalability, full replication of the entire blockchain in each node presents a challenge, as it leaves no room for parallel task execution and prevents sharding of the database (Christidis & Devetsikiotis, 2016). In contrast, partial distributed replication is used in traditional *“big data”* databases to enable high throughput and scalability of the system (McConaghy et al. 2016). As a result, many blockchain systems fall short on modern transaction requirements such as payment processing and emails. As an example, the Bitcoin blockchain is capable of processing merely 7 transactions per second whereas, centralized payment processors like Visa averages 2 000 transaction per second, and can reach peak values of 56 000 transactions per second (Croman et al. 2016). However, the recent progress in this domain demonstrates promising solutions. For example, the Coco Framework by Microsoft Azure can be implemented in existing blockchain networks such as Ethereum or Hyperledger to achieve rates as high as 1 600 transactions per second, by establishing trusted execution environments (Microsoft, 2017). In addition, as the blockchain database can only be appended, size will eventually become a challenge (Christidis & Devetsikiotis, 2016). Ironically, this also increases centralization of the network, as while the amount of data grows, only those with the resources to hold all the data will be able to participate (McConaghy et al. 2016).

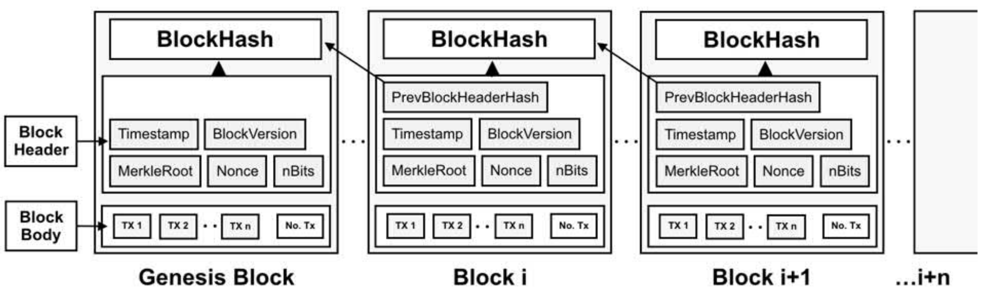

Figure 4. Simplified blockchain (adapted from Tschorsch & Schauermann, 2016; Zheng et al. 2017)

Each individual block consists of components that form the block hash, namely; block version, previous block header hash, merkle tree root, timestamp, nBits, and nonce. The block version determines the set of block validation rules to follow. The hash value of the previous block points to the previous block. The merkle tree root is essentially a hash value of all the transactions in the block. This technique is applied in order to optimize the verification of transactions in high quantities. The time stamp indicates the current time as seconds in universal time. The nBits is a target threshold value of a valid block, whereas the nonce is a random number that is added into the block – both which are not necessarily required, depending on the applied consensus mechanism. (Zheng et al. 2017)

2.4. Protocol

The Encyclopaedia Britannica (2016) defines protocol in computer science as *"a set of rules or procedures for transmitting data between electronic devices, such as computers"*. Accordingly, a protocol in a blockchain system defines how transactions are conducted within its boundaries (Swan, 2015, 1; Christidis & Devetsikiotis, 2016). It also consists of the validation scheme applied in the system and determines the distribution and creation of tokens (Tschorsch & Schauermann, 2016). The purpose of the verification process is to achieve consensus on the content of the public ledger, while the integrity of the blockchain is ensured by cryptographic techniques (Weber et al. 2016).

2.4.1. Cryptography

In the core of the protocol, hashing of data combined with timestamping enables secure and tamper-proof blockchain transactions (Swan, 2015; 37; Christidis & Devetsikiotis, 2016). Hashing in cryptography refers to mathematical one-way functions that map arbitrary length data inputs into bit strings of fixed size from which the original input cannot be inverted (Al-Kuwari et al. 2010). This hash represents the exact content of original file that can be verified by running the hash function over the original file (Swan, 2015; 37). Thus, a hash value can be considered as the unique fingerprint of the data file.

	Sender has	Recipient has
Signing	Sender private key	Sender public key
Encrypting	Recipient public key	Recipient private key

Table 2. Key requirements for public/private key signatures and encryption (adapted from Microsoft TechNet, 2005)

Blockchain protocol groups hashed transactions into blocks that are digitally signed and encrypted (Weber et al. 2016). The requirements for these functions are presented in the table 2. In blockchain systems, the signatures and encryptions are based on *Public/Private Key cryptography*, in which a private and a public key, generated through elliptic curve cryptography, form a pair in a way that each key can only be used in conjunction with the other key in the pair (Diffie & Hellman 1976; Miller, 1985). Thus, a transmission consists of the hash value of the message combined with a key.

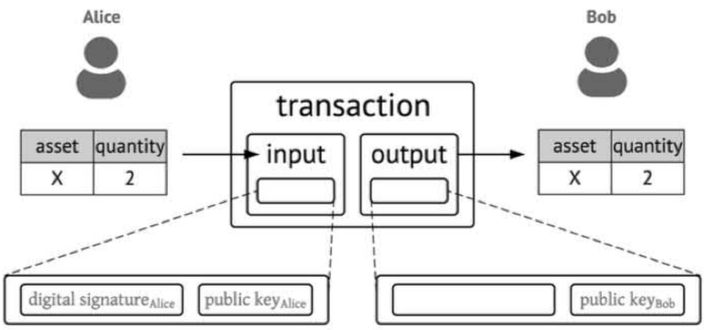

Figure 5. Transactions in blockchain systems (Christidis & Devetsikiotis, 2016)

As the two keys form a pair, an encrypted transaction addressed to a public key can only be decrypted by possessing the corresponding private key (Christidis & Devetsikiotis, 2016). Because signatures can only be created by using a private key, the validity of a signature can always be confirmed through the corresponding public key (Anderson et al. 2016). In blockchain systems, a public key typically refers to an address of a node and is hashed with algorithms such as SHA-256 for increased security (Swan, 2015, 98). It is critical that the private key remains as a secret, as if in the example transaction presented in the figure 5, Alice would gain access to Bob's private key, she would be able to claim all the transactions in the network addressed to Bob's public key. This also means that the integrity of the digital signatures is highly dependent on the security of the private key.

2.4.2. Transactions

Transactions on the blockchain are often tied to a specified cost, represented by *tokens*. These tokens represent value and currencies that grant access to applications and act as keys for the execution and tracking of digital transactions (Swan, 2015, 70-71; Hasse et al. 2016). Transaction in a blockchain network consists of a hash value as the transaction identifier and a list of inputs and outputs (Tschorsch & Schauermann, 2016). To keep track of the balance of tokens per each node, the blockchain ledger stores the complete transaction history of the system and verifies transactions through their links to previous transactions (Christidis & Devetsikiotis, 2016). Output of a transaction is categorized either as an unspent transaction output if it has not been referenced by a subsequent transaction so far, or as a spent transaction output (Tschorsch & Schauermann, 2016). Inputs must be used completely to complete a transaction and each transaction can only be used once as an input (Herrera-Joancomartí & Pérez-Solá, 2016). A schematic model on blockchain transactions is presented in the figure 6. It is important to emphasize that the transaction chain keeps track of how ownership of tokens changes whereas the blockchain tracks the order of the valid transactions.

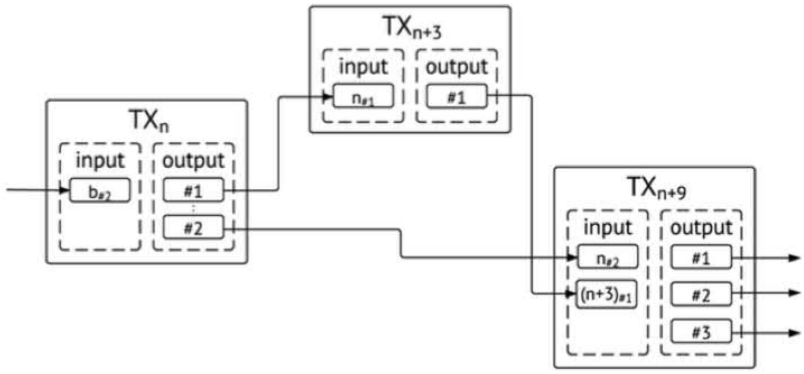

Figure 6. Linking of transactions in blockchain systems (Christidis & Devetsikiotis, 2016)

Blockchain systems utilize a flooding technique to relay transmissions across the network. To validate a transaction, the nodes in the network check the inputs to confirm that they are unspent. If the signed transaction is properly formed, valid and complete, it is first sent to neighbouring nodes on the blockchain network, which will further validate it and send it to their peers until the transmission reaches every node in the network. The sender does not need to trust the relay nodes used to broadcast the transactions, as long as more than one is used to ensure the propagation of the transmission. The recipient, on the other hand, does not need to trust the sender, because the transaction is signed and can be verified through the sender's public key. (Tschorsch & Schauermann, 2016; Weber et al. 2016)

2.4.3. Consensus mechanism

Completed transactions are grouped into blocks and broadcasted in the network. The transactions recorded in a block are considered as confirmed, whereas the rest of the transactions conducted in the network remain as unconfirmed or unordered. Adding a block to the blockchain is known as *mining* – a process that is distributed and that can be voluntarily performed by the nodes of the network according the applied protocol. As the integrity of the network is highly dependent on the mining process, incentives are often provided to ensure that a large number of nodes participate in the process, thus distributing the validation of blocks and preventing centralization of power and influence. (Christidis & Devetsikiotis, 2016; Zheng et al. 2017)

Due to the distribution of the mining process, there might be multiple simultaneous suggestions for a block. Hence, consensus must be reached in the network on which block should be added into the chain and if the content of the payload is valid. As the nodes of the network might be unknown to each other, a risk for Sybil attacks and the Byzantine Generals problem exists. The Sybil attack refers to an event in which a node is able to join the network under multiple identities, gaining unfair power and influence over the other participants, whereas the Byzantine Generals problem describes collective decision making under a constraint of nodes may fail in arbitrary ways, for example as a result of malicious behaviour. A consensus algorithm which enables a distributed system to come to consensus despite of these faults, is referred to as Byzantine Fault Tolerant (BFT). (Tschorsch & Schauermann, 2016; McConaghy et al. 2016)

Occasionally two different blocks can be chosen into the blockchain at the same time. This results in a *forking* of the blockchain as demonstrated in the figure 7. This issue can be solved by adding the following blocks into the longest known fork involving the highest amount of effort or value so far. It is highly unlikely that any single node would be able to validate blocks multiple times in a row or that multiple blocks are validated at the same time, as the design of a good consensus mechanism aims to prevent this. Also, as each block must contain the hash value of its parent, mining of blocks "in advance" is prevented. Eventually, only one fork survives and the network once again reaches consensus on the content of the ledger, invalidating the other fork and its transactions as orphaned. (Christidis & Devetsikiotis, 2016; Herrera-Joancomartí & Pérez-Solá, 2016; Tschorsch & Schauermann, 2016)

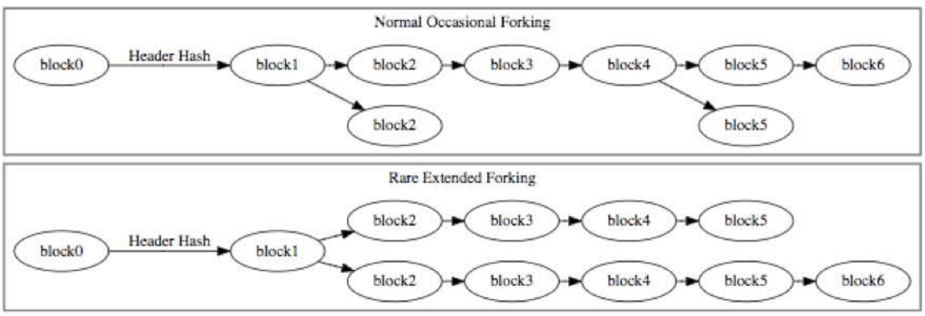

Figure 7. Forking of the blockchain (Bitcoin, 2016)

When a branch of the chain is orphaned, the transactions included in its blocks are returned into the pool of unconfirmed transactions. Thus, network participants are usually suggested to wait for a certain number of new blocks to be validated before a transaction can be considered as confirmed. Because blockchain systems have different parameters for determining new block validation interval, the timespan for successful transactions varies. The time taken to validate a block depends on the complexity of the process, thus positively correlating with increased security of the validation scheme. However, this latency creates a significant bottleneck for the throughput of the blockchain system. (Natoli & Gramoli, 2016)

Consensus mechanism could essentially be as simple as a voting system. This would create an ideal and cost-effective scenario, in which the network agrees on the order of the blocks in the chain by voting. A federation consensus is an example of such system, in which each member has an equal vote and the federation sets the rules of the different roles in the network and who can join as a voter. Typically, the majority of voters must agree to reach consensus. In general terms, higher number of voters results in a more decentralized system, but increases latency. However, due to a risk of Sybil attacks, the federation model is not applicable in anonymous open networks. This issue can be solved by applying consensus mechanisms that make mining of blocks expensive in some way and provide incentives for transaction validation. (Christidis & Devetsikiotis, 2016; McConaghy et al. 2016) Hence, alternative consensus models must also be considered.

Proof of work (POW) is a consensus scheme that incorporates a complicated computational process for authenticating blocks. The process incorporates nodes repeatedly calculating a hash over the block being validated, together with a nonce of their choosing. A block will be accepted by the network if the calculated hash value is below a given target value. When a miner finds a valid hash, the block is announced to the network. In this sense, POW can be compared to a lock that opens only with a right combination that has to be guessed. The difficulty of the computation is adjusted automatically in accordance to the total computing power of the network so that someone will find the solution in regular intervals. (Christidis & Devetsikiotis, 2016)

Due to its computational complexity POW is often considered as a waste of resources. Hence, establishment of significant incentives for participation are required. Repeatedly calculating hash values is expensive due to energy requirements of the CPUs used in the process. Energy is wasted on each calculation that does not yield the required hash value, meaning that a significant amount of resources is committed only to facilitate the validation of transactions, without any other practical use. Due to the costs involved and the difficulty of the process, it is often not profitable for a single node to participate in POW mining. (Tschorsch & Schauermann, 2016)

Proof of stake (POS) is an energy-saving alternative to POW. The idea of POS is to assign the right to mine a block based on an ability to demonstrate that the miner holds a certain stake in the network, which is measured by the value of tokens in possession. Importantly, anyone can join the process of securing a block with respect to the size of the stake invested into the network. This investment is measured in terms of coin age, which is effectively the number of tokens multiplied by the holding period. As no computation gear is required, POS eliminates the high energy consumption, while offering a secure method for reaching consensus in an open network. (Weber et al. 2016; Zheng et al. 2017)

The major weakness of POS is that coin age accumulates even when the node is not connected to the network, resulting in peaks of reward distribution and decreased level of security than in the case where nodes remain online all the time. To incentivize nodes to stay online, POS scheme can be modified to include a proof of activity (POA) mechanism. In POA, the objective is to reduce the resistance to trade tokens and to encourage users to stay online by decreasing the increment rate of the coin age with time, asymptotically converging to zero. This means that a fresh token accumulates coin age much faster up to a fixed threshold, encouraging nodes to participate to the mining process early on. (Tschorsch & Schauermann, 2016)

2.5. Smart contracts

The top level of the blockchain technology stack constitutes of applications running in the blockchain. The most practical examples of such applications are smart contracts, that are user-defined constructs of code that are publicly visible and are executed across the whole network by all the connected nodes (Weber et al. 2016). Clack et al. (2016) define smart contracts as, *"agreements whose execution is both automatable and enforceable; automatable by computer, although some parts may require human input and control; enforceable by either legal enforcement of rights and obligations or tamper-proof execution."* Smart contracts are triggered by addressing a transaction to it (Christidis & Devetsikiotis, 2016). Once established, these applications are immutable, unstoppable, and irrefutable (Wall, 2016). Only the authorized users, defined in the code, are able to end the contract though a suicide command (Anderson et al. 2016).

Smart contracts are deterministic, meaning that a certain input will always produce the same output across the whole network (Christidis & Devetsikiotis, 2016). These applications can be, for example, used to reach an agreement, solve problems and facilitate automation (Anderson et al. 2016; Wall, 2016). Smart contracts are complex entities, as they are capable of triggering other sub-contracts and can even have storage (Weber et al. 2016). Because of these characteristics, smart contracts must by code declare what will happen in every possible event during the life time of the contract (Wall, 2016). This creates challenges from security and legal perspectives. For example, any large piece of computer code almost surely contains bugs, and if the contract is written incorrectly, any interactions with it cannot be undone (Christidis & Devetsikiotis, 2016; Weber et al. 2016). Also, in contrast to traditional agreements which are typically incomplete by purpose (Halonen-Akatwijuka & Hart, 2013), current smart contracts do not leave room for renegotiation (Wall, 2016). Despite of their limitations, smart contracts represent an essential function in the modern blockchain technology stack, enabling process automation and the usage of the technology in an increasing number of applications.

2.6. Interface to external environment

Blockchain systems are confined domains with no direct capabilities of interacting with entities outside of the system (Weber et al. 2016). As a result, for example smart contracts are not able to utilize information generated outside of the blockchain. This is due to the fact, that it is inefficient and often impossible to reach a decentralized consensus on centralized data (Oraclize, 2017). However, in many instances, such parameters are required to fill the conditions set in a smart contract, which triggers events on the blockchain. This problem can be solved by utilizing Oracles, functioning as agents that find and verify real world occurrences and submit this information to a blockchain to be used by smart contracts (Consensys, 2016).

However, a challenge remains, as the Oracles are not a part of the blockchain consensus mechanism, and yet the data feed needs to be trusted, whether it is hardware sensor data or website information. Service providers such as Oraclize (2017) solve this issue by returning the data requested by the smart contract itself, along with a proof of the authenticity, proving that the data comes from the data provider which has been explicitly demanded by the smart contract. Thus, an Oracle represents a trusted third-party that mediates transactions between blockchain systems and centralized databases. Even though the core ideology of the blockchain technology is to bypass all intermediaries, this is not applicable when dealing with information outside the blockchain. In this sense, trust is not needed inside the blockchain domain, but interaction with external systems requires a mediator. However, this still dramatically reduces transactional complexity, as only one trusted third party is needed, and only when engaging with entities hosted outside the blockchain environment. It is important to keep in mind, that a blockchain database entry is merely a proof that someone put it there permanently, but it does not itself guarantee the validity of the asset in the real world.

2.7. Permissioned blockchains

This technology review has addressed blockchains as open systems, where all records are visible to the public and each node has the option to participate to the distributed consensus process applied in the system. Such systems have been criticized to rely on game-theoretic and incentive-based consensus mechanisms, resulting in overly slow and expensive applications for many business use-cases (Setty et al. 2017). Hence, it is necessary to consider an alternative blockchain structure known as either permissioned -, private -, or consortium blockchain. This system structure applies the principles of the blockchain technology into a centralized network to create a controlled environment while taking the advantage of the benefits of the technology platform. In this context, permissions refer to rules about what a user can do with a piece of data. Such permissioned blockchains are decentralized databases that are controlled by a single entity, whereas consortium blockchains are being controlled by multiple entities engaged in cooperation (Buterin, 2015). The core entity in control of the blockchain network is referred to as the blockchain service provider (Setty et al. 2017).

Permissioned blockchains are developed to meet the custom needs of different businesses and industries. These private blockchains refer to distributed networks where a whitelist is in place, containing access rights and security settings for identified users (Christidis & Devetsikiotis, 2016). Table 3 lists the most important objectives and benefits of permissioned blockchain networks. In business context, this kind of controlled environments are often preferred, as they facilitate creation of competitive advantage through differentiation, innovation and protection.

#	**Objectives and benefits of permissioned blockchain networks**
1	Ensure that the activity inside the blockchain is only visible to chosen participants
2	Introduce controls over which transactions are permitted
3	Enables block validation and consensus to take place securely and efficiently without association high costs typically present in public blockchains

Table 3. Objectives and benefits of permissioned blockchain networks (Greenspan, 2015a)

The permissioned blockchains diverge from the original peer-to-peer ideology of the blockchain by increasing centralization and asymmetric power relations in the network. This means that trust is increasingly placed on the blockchain host, rather than the system itself. Thus, private blockchains cannot be considered as decentralized networks, as they are controlled by specific entities. (Zheng et al. 2017) Due to this characteristic, consensus and incentive systems are not even necessarily required in private chains, as there is no danger of Sybil attacks in a network where all nodes are known and registered entities (Christidis & Devetsikiotis, 2016). However, utilization of consensus mechanisms such as Paxos, Raft (Ongaro & Ousterhout, 2014), or Caesar may still be necessary and beneficial in detecting misbehaviour by the blockchain service provider, recover from such events, and to reach consensus on the ledger (Setty et al. 2017). The benefit of the private blockchains is that through customization and controllability, they offer solutions to many issues currently hindering the development of public blockchains, by enabling scalability and high throughput volumes in exchange to anonymity and transparency (Greenspan, 2015a; Weber et al. 2016; Yli-Huumo et al. 2016).

3. Technological perspective on organizational transformations

This chapter discusses organizational transformations from a technological perspective. First, the characteristics of networked organizations are reviewed through an analogy of ecosystems. Secondly, technology and institutions are defined in terms of their significance as the core dimensions of organizations. Then, the concept of innovation is explored by elaborating the systemic dependencies within organizational transformation processes. Further specifying the scope of interest, technological transitions are introduced for developing a deeper understanding on the mechanisms through which technologies bring about profound changes in systemic organizations. Finally, focus is aimed towards the enabling factors for creating windows of opportunities for such transformations. Summarizing the findings of this chapter, a theoretical framework is introduced to synthesize the key components that mediate the implications of emerging technologies in systemic transformations.

3.1. Ecosystems as organizational constructs

Modern business environment can be described as a networked information economy, in which positive feedback and network effects mediate the dynamics of competitive advantage (Shapiro & Varian, 1999). In this environment, embedded in a social system structure, tensions arise from a myriad of multi-sided activities. Under these dynamics, organizations engage in relationships with each other within and across industries for a variety of reasons, that are extensively discussed by literature streams such as transaction cost economics (Williamson, 1981) and resource based view (Teece et al. 1997). This setting places an increased emphasis on the management of resources and information in complex systems of interconnected actors, traditionally referred to as the interorganizational network (Hatch, 1997, 65). Therefore, it is acknowledged that the foundations of modern successful organizations are built on a comprehension of how value is created and captured rather in the interconnected networks in which they operate, than in individual silos of processes and activities (Davidson et al. 2015).

In order to conceptualize the complexity of modern business and social structures, a concept of business ecosystems is often employed by creating an analogy of natural ecosystems that renew themselves after collapsing due to radical changes in the environment. Such business ecosystem structure emphasizes the mutual dependence and interplay between the actors in a network system, just as in biological or natural ecosystems in which random collection of elements gradually form into a structured community through natural selection – the survival of the fittest. In business context, the environment changes as a result of co-evolution, consisting of competitive and cooperative business strategies. (Moore, 1993)

As a generic model, the development of business ecosystems consists of four stages; *(i) birth, (ii) expansion, (iii) leadership,* and *(iv) self-renewal*. Birth stage involves entrepreneurs defining their value propositions and what the customers want. It emphasizes cooperative processes, while also protecting own intellectual properties to ensure competitive advantage. In expansion stage, battle for market share breaks out as rivalling ecosystems pressure suppliers and customers to join up. This can be described as a clash of the ecosystems. Leadership involves with guiding the ecosystem's investment directions and technical standards and maintaining bargaining power by controlling the key elements of value creation. Importantly, leadership is about encouraging and developing the ecosystem evolution to improve value creation. Finally, self-renewal occurs as a result of rising new ecosystems and innovations. It is important to be able to scan the environment for potential disruptors and innovate continuously to keep the virtuous cycle running. For a business ecosystem, failure in self-renewal ultimately leads to its death. (Moore, 1993)

Business ecosystems are networked systems characterized by fragmentation, interconnectedness, cooperation and competition (Iansiti & Levien, 2004a). From this perspective, organizations are not merely seen as members of single industries, but rather as parts of business ecosystems that span cross a variety of industries (Moore, 1993). In this complex structure, actors may in fact participate in multiple business ecosystems (Aarikka-Stenroos & Ritala, 2017). Thus, ecosystems may be considered as collections of multiple organizational fields, which individually represent *"those organizations that, in the aggregate, constitute a recognized area of institutional life: Key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products"* (DiMaggio & Powell, 1983).

In order to contain focus and overcome the problem on setting arbitrary boundaries for networked systems, researchers often place their organizations of interest into the centre of scope (Hatch, 1997, 65). More specifically, research suggests shared logic, governance, technological interdependencies and value logic as appropriate parameters for defining boundaries of an ecosystem construct (Thomas & Autio, 2014). On a fine-grained level, ecosystem actors are considered to incorporate different roles in the network, such as keystone, dominator, or niche player (Iansiti & Levien, 2004a; 2004b). Together these stakeholders stimulate a cycle of creative destruction and build efficiency improvement for the entire network (Williamson & De Meyer, 2012). Importantly, all individual business activities share the fate of the whole community (Moore, 2006). Hence, business ecosystems are considered as networks of actors engaged in joint value creation (Overholm, 2015), characterized by symbiosis, platform model and co-evolution (Li, 2009). According to a more recent notion, the ecosystem can be conceptualized as a standalone definition describing *"the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize"* (Adner, 2017). Importantly, as highlighted by Aarikka-Stenroos and Ritala (2017), *"ecosystems do not include only the actors that are directly or indirectly connected to a network, but also the actors, technologies, and institutions that are interdependent with less formal and looser manner".*

Modern academic literature embraces the concept of business ecosystem thinking in a broad range of conceptualizations. For example, ecosystems have been studied in contexts such as innovation (Adner & Kapoor, 2010), platforms (Gawer & Cusumano, 2014), entrepreneurship (Overholm, 2015; Hellström et al. 2015), and services (Lusch et al. 2016). Despite of the differences in the selection of focal actors, and thus the focus of interest, the business ecosystem literature is consistent with an interest in co-evolution that refers to multiple dynamics that interact with one another over time, and boundaries and composition that define the context in which the relevant set of actors, technologies, and institutions is situated (Aarikka-Stenroos & Ritala, 2017).

Ecosystem type	Description
Business ecosystem	Ecosystems consisting of both upstream and downstream value network actors and related technologies and institutions
Innovation ecosystem	Ecosystems consisting of actors, technologies, and institutions that enable innovation
Entrepreneurial / start-up ecosystem	Ecosystems enabling the emergence and growth of new businesses
Platform ecosystem	Ecosystems based on a digital platform
Service ecosystem	Ecosystems based on service- dominant logic

Table 4. Major ecosystem literature streams and their characteristics (Aarikka-Stenroos & Ritala, 2017)

The emergence of ecosystems is a complex non-linear process involving co-creation activities and interdependencies among diverse sets of stakeholders (Adner & Kapoor, 2015; Ansari et al. 2016; Aarikka-Stenroos & Ritala, 2017). Such interdependency in value creation may create significant complications especially in the early stages of development. For example, in case the value proposition of the ecosystem correlates with the value of its components, and none of these components are valuable in isolation, a challenge emerges on how to resolve uncertainties, and encourage initial commitment and collective participation (Dattée et al. 2017). Such chicken-and-egg-problem is rather typical for platform ecosystems where no participant group will join without another (Eisenmann, 2008). Additional challenges may emerge, as in fear of becoming underdogs in value capture potential, organizations are often reluctant to submit into operating within systems controlled by others (Mattila et al. 2016a). Literature often proposes a solution to such issues through an establishment of strong leadership and compelling blueprints that define the ecosystem's future in terms of value proposition, and associated structures of governance and interaction (Iansiti & Levien, 2004b; Adner, 2006; Williamson & De Meyer, 2012). However, according to the findings of Dattée et al. (2017) such envisioning is not possible in the case of ecosystems based on generative technologies that have the potential to produce unprompted change and to create an unbounded variety of applications, resulting in a scenario in which ecosystem actors adopt a tentative stance for discovery and engage in activity based on their anticipations of value capture. This notion reveals the importance of considering ecosystems from a technological perspective, especially in the context of the cognitive processes through which ecosystem actors resolve uncertainties and commit to activity.

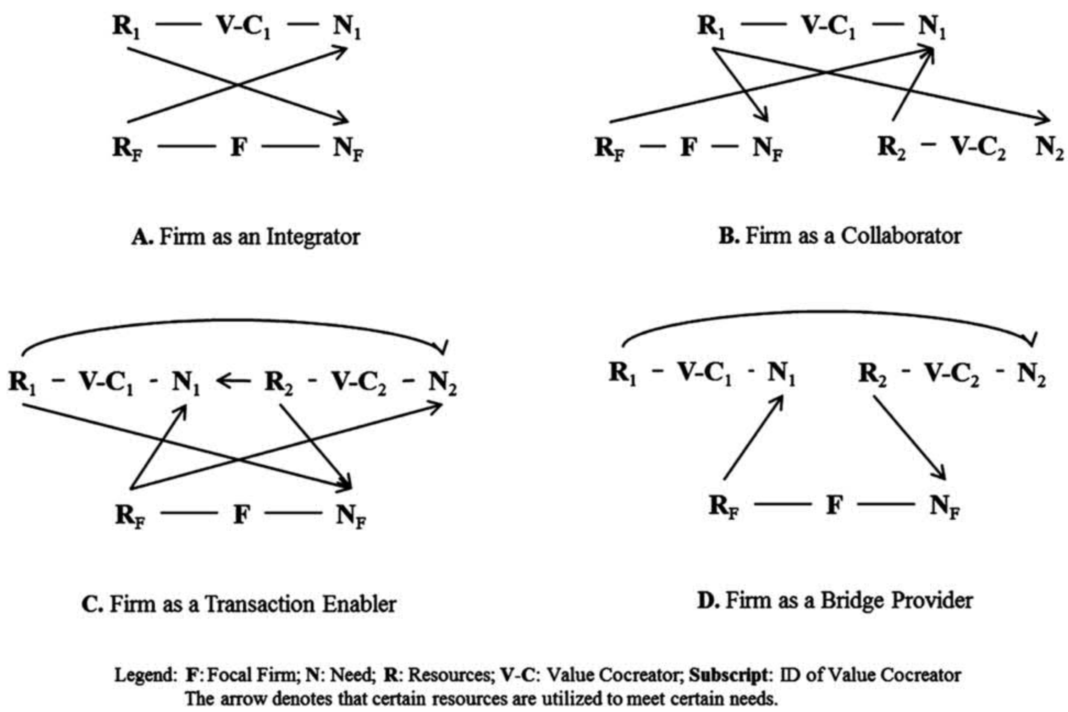

Figure 8. Resource configuration prototypes (Amit & Han, 2017)

In terms of structure and arrangement, ecosystems consist of a myriad of actors that implement a wide range of strategies in their operations. This emphasizes the importance of understanding the value creation processes, and how resources are configured within ecosystems. Amit and Han (2017) illustrate four typologies for resource configurations that describe the distinct roles of organizations in systemic structures (figure 8). The prototype A describes the traditional “brick and mortar” firms that transform resources to address the demand, while the customers contribute to the revenue of the focal firm with their resources. In prototype B, however, the focal firm engages in collaboration with a partner that provides complementarities for the offering. Both firms create value together for the customers, thus also sharing the received value. In addition, the developing digitalization has enabled new modes of activity in organizations. For example, the expansion of both accessible resources and addressable needs has enabled value creation opportunities in transaction facilitation, as presented in the prototype C. Such model can be conceptualized for example as an online pricing comparison service, in which a firm contributes resources to facilitate or enable transactions between groups of value co-creators whose needs can be addressed by the other group's resources. A firm may also act as a bridge between value co-creators, as demonstrated in the prototype D. In this scenario, that can be elaborated by referring to Google's business model on advertising, the value co-creators cannot interact with each other without the existence of the focal firm. Both prototypes C and D are examples of the emerging ecosystem thinking in business model development. Yet, the resource configurations are not exhaustive, as organizations, and thus ecosystems, may in fact simultaneously incorporate features from multiple typologies. Overall, the above presented framework provides an essential layer of detail in the exploration of ecosystem structures, emphasizing the variable positioning of actors and stakeholders, while identifying that value creation fundamentally spawns from identifying, matching, and bridging needs and resources. (Amit & Han, 2017)

3.2. Core technologies and institutions

In addition to networks of interconnected actors, ecosystems consist of technologies and institutions (Aarikka-Stenroos & Ritala, 2017). Technology represents an organizational domain consisting of dynamic resources and technological frameworks that are shared by the ecosystem stakeholders (Gawer & Cusumano, 2014; Vargo et al. 2015). Institutions refer not only to the underlying regulative, normative, and cognitive contexts of the organizational fields (Scott, 2001, 48), but also to the relevant regulators, policymakers, and interest groups (Vargo et al. 2015; Ansari et al. 2016; Granqvist & Gustafsson, 2016). These institutions govern the patterns of interaction within the technological frameworks (Garud et al. 2002).

From an organizational perspective, technologies are defined as "*multi-dimensional constructs of (i) physical objects or artefacts, (ii) activities or processes and (iii) the knowledge needed to develop and apply these*". In essence, technologies describe transformation processes of converting inputs into outputs. (Hatch, 1997, 128-130) Such definition suggests that technology refers to a wide range of phenomena that are used to fulfil various purposes. Modifying any of the dimensions of a technology essentially changes the technology itself. What then distinguishes less sophisticated technologies from new technologies, is complexity and the level of automation – the extent to which the technology consists of stochastic, continuous, and abstract events (Weick, 1990). Such ever-increasing technological complexity entails an increase also in structural complexity of organizations, resulting in a need for a higher level of coordination and collaboration across organizational borders (Galbraith, 1973). Consequently, the importance of special boundary roles, mediating information transfer across organizational levels and borders, is emphasized (Tushman, 1977).

Figure 9. Basic open systems model of the organization (Hatch, 1997, 130)

Defining the level of analysis on technologies is imperative, as organizations utilize multiple concurrent technologies on different levels (e.g. organization, unit, and task) to achieve the final objectives on producing the outputs needed and desired by the society. Each of these levels incorporate the three dimensions of technology as previously defined. Thus, a holistic view on a technology is created from multiple analyses on different organizational levels. This kind of analysis is often inadequate due to high complexity. Consequently, technologies can be simplified and downplayed into an organizational level, allowing a comparison of technologies across different organizations. The result of this abstraction unveils the core technology of an organization, but loses the details of technological diversity in organizations. (Hatch, 1997, 128-131)

- *"Technology, of itself, has no power, does nothing. Only in association with human agency and social structures and organisations does technology fulfil functions." (Geels, 2002)*

Technologies exist embedded in the institutional environments that shape them. Such institutional space consisting of social rules, norms, values, meanings, and beliefs is required to provide the rules that govern the production, distribution and consumption associated with technologies. (Garud et al. 2002) Hence, institutions are essential enablers of novel ways for value creation (Vargo et al. 2015), while the collection of the most important institutions in a specific context may be considered as the core institutions. As institutions are dynamic constructs, the concept of institutional work, referring to the creation, maintenance, and disruption of institutions, is established as a central process in technology development (Lawrence & Suddaby, 2006, 215). Such process describes the manner in which interested actors work to influence their institutional contexts (Garud et al. 2002), thus also shaping technological development trajectories. Consequently, understanding the forms of institutional work conducted in the organizational domain is essential.

Forms of institutional work		
Creating institutions	**Maintaining institutions**	**Disrupting institutions**
Advocacy	Enabling work	Disconnecting sanctions
Defining	Policing	Disassociating moral foundations
Vesting	Deterring	Undermining assumptions and beliefs
Constructing identities	Valourizing and demonizing	
Constructing normative networks	Mythologizing	
Mimicry	Embedding and routinizing	
Theorizing		
Educating		

Table 5. Forms of institutional work (Lawrence & Suddaby, 2006, 221, 230, 235)

Institutional work consists of three main categories of creation, maintenance, and disruption, that include activities which may exist and be utilized concurrently. Creation of institutions refers to three sub-categories. Firstly, advocacy, defining, and vesting refer to political work, in which actors reconstruct rules that define access to resources. Constructing identities, changing norms, and constructing networks then emphasize actions in which actors' belief systems are reconfigured. Finally, mimicry, theorizing, and educating are utilized to alter abstract categorizations in which the boundaries of meaning systems are altered. In general, maintaining institutional work involves supporting, repairing or recreating the social mechanisms that ensure compliance. More specifically, enabling work, policing, and deterring aim to ensure adherence to rule systems. Valourizing and demonizing, mythologizing, and embedding and routinizing, on the other hand aim to maintain institutions by reproducing existing norms and belief systems. Yet, the existing institutional arrangements cannot serve the interest of all possible actors. Consequently, the emergence of actors who attempt to disrupt the extant set of institutions, is highly probable. These actors engage in activities that involve attacking or undermining the mechanisms that lead members to comply with institutions. (Lawrence & Suddaby, 2006, 221, 230, 235)

3.3. Innovation processes in ecosystems

Literature has consistently demonstrated how innovations cause markets to behave differently (Nagy et al. 2016). The concept of innovation incorporates an important role in the development of technology frameworks, and includes a process of institutional creation, maintenance, and disruption which requires the integration of new technologies with existing institutions, and results in the development of new value propositions (Vargo et al. 2015). Indeed, new markets do not emerge in their full scale but rather evolve from messy, uncertain and risky environments with dubious growth prospects (Tidd et al. 2005, 31). Hence, the role of the institutional environment in innovation processes is emphasized, as it mediates the development of the technologies (Garud et al. 2002). In other words, innovation adoption may be dampened by the institutional domain, while innovation may also trigger and drive activities that aim to change the institutions. As the level of adoption increases, innovations begin to shape their surrounding system structures and institutions (Ansari et al. 2016). This is referred to as disruption, which brings about profound changes to markets, society, and the arrangement of roles and structures (Riemer & Johnston, 2016). However, disruption is a paradoxical and complex process that incorporates challenges for both the ecosystem incumbents and disruptors (Ansari et al. 2016). Navigating in business environments under such conditions is not a simple task. Thus, closer examination of innovations processes in networked system structures is required.

The origins of the term “innovation” stems from the literature by an Austrian economist Joseph A. Schumpeter, who described a trilogy of invention that is divided into three stages; (i) *invention* – generation of new ideas, (ii) *innovation* – encompassing the development of new ideas into marketable products or processes, and (iii) *diffusion* – new products and technology spreads across the potential market (Schumpeter, 1927). These three stages form the foundations of the initial framework on the development of new technologies (Jaffe & Stavins, 1995). According to a canonical definition, innovation is often described as *“an idea, practice or object that is perceived as new by an individual or other unit of adoption”* (Rogers, 2003). An important remark is that the process of innovation involves not only inventing new or improving current products, processes or functions, but also growing them into a practical use (Tidd et al. 2005, 3).

Innovation as a concept is a relative and context dependent subject (Nagy et al. 2016). Indeed, defining the scope of the analysis is important, as change can happen at component or sub-system level or across the whole system (Tidd et al. 2005, 12). In order to conceptualize such changes, typologies are often used to describe innovations and their characteristics. *Sustaining innovations* improve the performance of established objects of interest incrementally or radically within the expectations and valuations of the mainstream markets (Christensen, 1997). In contrast, *disruptive innovations* refer to *“innovations with radical functionality, discontinuous technical standards, and/or new forms of ownership that redefine marketplace expectations”* (Nagy et al. 2016). Innovations that incorporate a high level of novelty are considered as *radical innovations*. This type of discontinuity occasionally arises, dramatically shifting the basic conditions of technology, markets, regulation and social structures. Tidd et al. (2015, 18) describe this as a change in the *“rules of the game”*, which opens up new opportunities for innovation. *Incremental innovations*, on the other hand, describe *“innovations that push the existing technological trajectory for existing subsystem and linking mechanisms”* (Tushman & Smith, 2004). It is important to note that an incremental innovation is also able to become disruptive, as through continuous improvement, it becomes a competitor for the market leader, thus disrupting the market status quo (Bower & Christensen, 1995).

Modern literature proposes innovations to develop as planned innovations or as reactions to change in the environment. In this context, Sundbo (2002) presents four principles for the emergence of innovations: First, innovations may be forced by changes in markets and industries. Second, innovations may be generated independently by the organization’s internal initiatives. Third, innovations are influenced by the decision makers’ interpretation of their environment and their choice of strategic actions. Finally, innovation requires internal and external social networks in order to tap into new ideas and resources. These findings conclude that pressure to innovate may originate from both internal and external development trajectories. (Sundbo, 2002)

Adoption of innovations has been traditionally analysed through a theory on the diffusion of innovations, first introduced in 1962 by Everett Rogers, according to whom *“diffusion is a process by which an innovation is communicated through certain channels over time among the members of a social system”.* Rogers identifies five attributes of innovations that determine the rate of their adoption, namely; relative advantage, compatibility, complexity, trialability, and observability. More specifically, innovations with higher level of the previously mentioned attributes are considered to diffuse more rapidly than other innovations. (Rogers, 2003) However, innovation becomes an increasingly complex construct in the context of networks and ecosystems. This being acknowledged, Adner (2012) describes an *“innovator’s blind spot”,* referring to a failure on seeing how success also depends on partners who themselves would need to innovate and agree to adapt in order for their efforts to succeed.

Co-evolutionary approach on innovation theories stresses the importance of network effects in the evolution of innovations and ecosystems. Indeed, innovations are dynamic configurations which evolve in unexpected ways, and whose relevance is relational to the pre-existing features of the host organizations (Clark & Staunton, 1989). Such co-evolutionary approach on innovation development aims to identify and solve the internal and external challenges that constrict the development of the focal innovation on both component and complement levels (Adner & Kapoor, 2010). Consequently, the realized performance of the focal technology is identified as a function of its interaction with the other elements of the system (Adner & Kapoor, 2015).

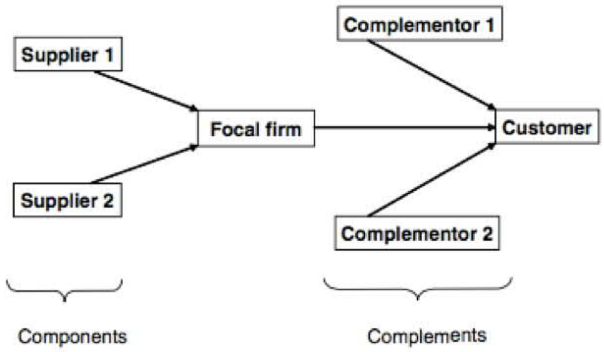

Figure 10. Generic schema of an ecosystem (Adner & Kapoor, 2010)

In a network context, co-innovation -, and adaptation chain risks stand to establish inertia in the diffusion of innovations (Adner, 2012). Consequently, these risks create bottlenecks constraining the realized performance of innovations, constituting the *ecosystem emergence challenge* (Adner & Kapoor, 2015). Hence, management of such risks is essential, as it is critical to ensure that the co-innovators of the network have solved their internal innovation challenges, and that the key-stakeholders agree on adapting the focal innovation (Adner, 2012). Yet, simultaneous improvements may develop in the incumbent innovations, further hindering the adoption rate of new innovations by establishing an *ecosystem extension opportunity* (Adner & Kapoor, 2015).

Development of innovations is a non-linear process subject to conflicting interests and demands of different stakeholders of the surrounding ecosystem structure. These conflicts facilitate coopetition – the presence of simultaneous cooperation and competition, that introduces significant complexity in ecosystem development trajectories. On one hand, organizations may be unable to develop new capabilities to cope with environmental changes due to an emphasis on sustaining the needs of their current customers. Yet, pursuing new innovations may result in self-cannibalization of the current business models and processes. This is known as the *innovator's dilemma*, on whether to disrupt or to be disrupted. On the other hand, organizations face difficulties in establishing their new innovations, because in order to build critical mass for adoption, they need support from the very incumbents and other ecosystem stakeholders that stand to be disrupted. This scenario is referred to as the *disruptor's dilemma*, which involves a balancing act in managing the dependencies and consequent spillovers across multiple networks connected to the ecosystem structure. This phenomenon is increasingly emphasized in systemic markets and industries. Consequently, the management of the disruptor's dilemma is more difficult for new market entrants with limited resources and influence, compared to established organizations. Overall, innovations develop in ecosystems as dynamic coopetitive processes, through which the ecosystem may eventually evolve to accommodate the new innovation, reframing destruction into creation. (Ansari et al. 2016)

3.4. Development of technological transitions

Technology can be viewed as a vehicle for an organizational paradigm shift. Simply put, it describes how things are done in the domain of interest (Hatch, 1997, 130). Hence, changing the technology effectively changes the status quo of the organization. Applying this concept into an interorganizational scope reveals implications on the transformative capability of technology in ecosystem structures. Building on the principles of the core technologies and institutions, and the innovation processes in ecosystem structures, this section introduces a concept of *technological transitions* as a framework to provide a deeper understanding on the mechanisms through which technologies bring about profound changes in systemic organizations embedded in their institutional environments.

F. W. Geels describes technological transitions (TT) as *"major technological changes in the way societal functions are fulfilled, involving changes not just in technology, but also in user practices, regulation, industrial networks, infrastructure and symbolic meaning or culture".* In total, seven socio-technical regimes are identified, representing institutions, structures and contexts for interaction between actors. These regimes are specified as *technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure (networks of suppliers, producers, distributors), policy and scientific knowledge.* (Geels, 2002)

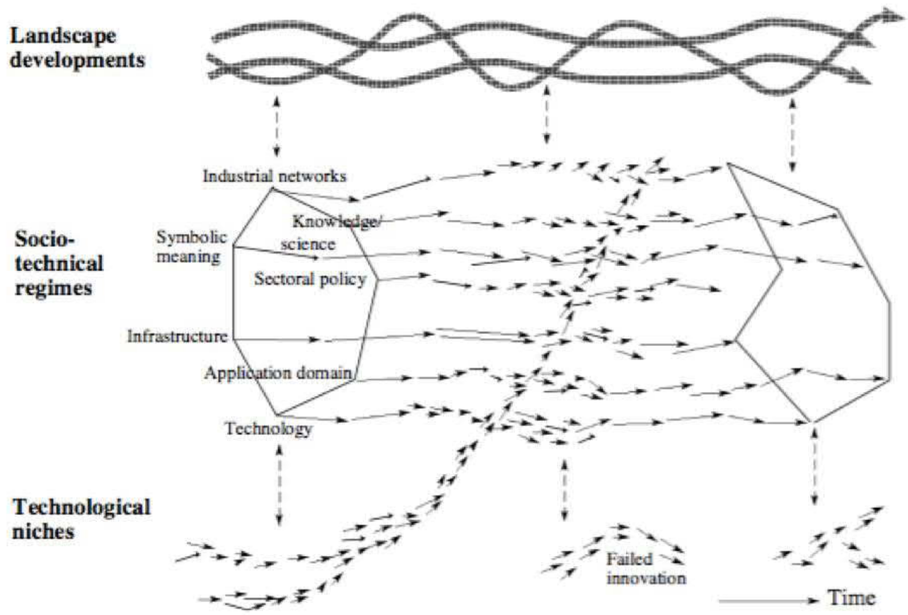

Figure 11. A dynamic multi-level perspective on technological transitions (Geels, 2002)

The framework discloses three levels of development. Firstly, *niches* are considered as specific application domains in which regular market conditions do not prevail, as the they are created through subsidies and alignments between various actors. This is where the seeds of change and variety are generated. Secondly, the *socio-technical regimes* describe interconnected and co-evolving semi-coherent sets of rules that have their internal dynamics. Rules in regimes are stable and specific, whereas rules in niches are fluid, broad and diffuse. Finally, *landscape* is considered as the wide context of our society, consisting of factors such as material and arrangements of infrastructures, but also macroeconomics, politics and cultural and normative values. (Geels, 2002; Geels & Schott, 2007)

Technological transitions occur as the outcome of linkages and interactions of developments at three levels. Thus, TTs are a result of stepwise reconfiguration processes that may not have to be rapid or revolutionary in nature, but can also result as an outcome of a series of incremental adaptation over time. Indeed, established configurations are characterised by inertia. Geels notes that "*radically new technologies usually have a hard time to enter established socio-technical regimes, because of misalignments with other elements or because of strategic opposition from firms with vested interests in the old technology".* (Geels, 2002)

In order for a TT to occur, the innovation must be aligned with the rules of the socio-technical regimes. Importantly, the interaction between the individual levels of TT is complex and bidirectional. Development in the regime dimensions may cause tension or misalignment of rules, or on the contrary, loosen up to form windows of opportunity for innovations to break out of their niches. (Geels, 2002) Further developing from the original concept, Geels and Schot (2007) propose that niche-innovations that are ready to break through the socio-technical regimes can be measured through the following proxies; (i) learning processes have stabilised in a dominant design, (ii) powerful actors have joined the support network, (iii) price/performance improvements have improved and there are strong expectations of further improvement, and (iv) the innovation is used in market niches, which cumulatively amount to more than 5% market share. In addition, the likelihood and the pathway of technological transitions are affected by landscape pressure that is described in a continuum of reinforcing and disruptive pressure on the dominant regimes, resulting in different transitional pathway archetypes labelled as *(i) transformation, (ii) de-alignment and re-alignment, (iii) technological substitution and (iv) reconfiguration* (Geels & Schot, 2007).

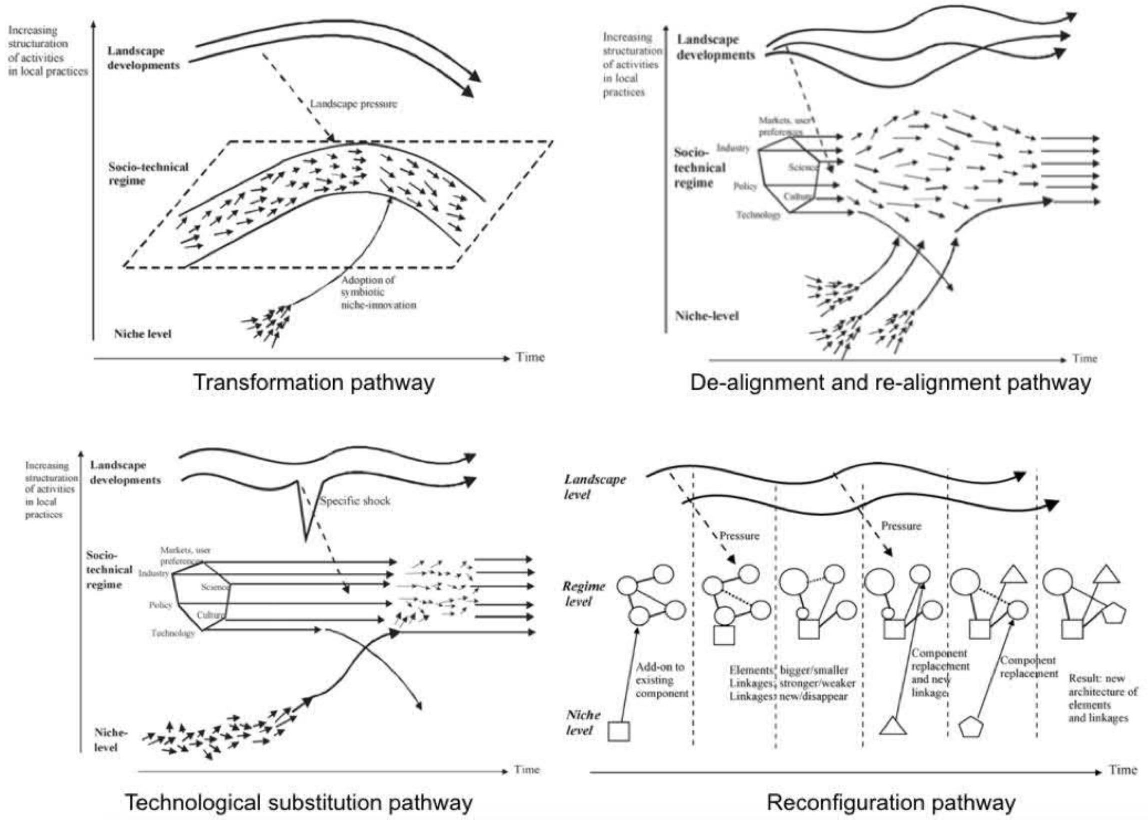

Figure 12. Pathways of technological transition (Geels & Schot, 2007)

Transformation path can be described as an incremental change affected by moderate pressure. Niche-innovations however, cannot take advantage of the landscape pressure if they are not sufficiently developed. *De-alignment and re-alignment* transitions occur as a result of divergent, large and sudden landscape changes, that cause the erosion of current regime structures, “hollowing out” the regime, when no stable niche-innovations capable of “filling the gap” are present. *Technological substitution* occurs as a result of a sudden shock in the landscape, providing a window of opportunity for stable niche-innovations with enough internal momentum to break through the established, but shocked regimes. Finally, *reconfiguration* may occur as technologies developed in niches are applied in the regimes to solve local issues, further changing the regime structure through incremental novelties and adaptation. (Geels & Schot, 2007)

3.5. Enabling windows of opportunities

The framework of technological transitions describes how significant organizational transformations occur when emerging technologies interfere, re-arrange, and become aligned with the rules of the dominant socio-technical regimes. However, by itself the model lacks detail on how the windows of opportunities for the transitions are actually created, rather considering such events as exogenous and unmodifiable givens that emerge as a result of arbitrary landscape pressure and regime development. Research suggests that the interorganizational domain consists of a myriad of opportunities that can be specifically developed and harnessed (Ansari et al. 2016; Overholm, 2015; Granqvist & Gustafsson, 2016). Moreover, the socio-technical regimes are embedded in institutional environments (Rip & Kemp, 1998, 340; Geels, 2002) that are subject to institutional work, describing how actors seek to influence their institutional contexts (Garud et al. 2002; Lawrence & Suddaby, 2006, 215). In addition to understanding that significant organizational changes, such as industry transformations typically occur in phases, and are rarely based on a single driver, there is an increasing need for developing knowledge on the factors that enable activity and commitment in such processes (Bergman et al. 2017). Following the findings of Dattée et al. (2017) on ecosystem actors committing to activity based on their anticipations of value capture, the following sub-chapters adopt a technological perspective for elaborating the cognitive processes through which emerging technologies interfere with systemic transformation trajectories.

3.5.1. Cognition and sensemaking

Technology is an equivocal concept that requires ongoing structuring and sensemaking in order to manage its development (Weick, 1990). Consequently, cognitive processes and mental models that people use to make sense of their world and to make decisions about what actions to take, are important in determining the outcomes of attempts to implement innovations (Swan, 1995). However, not all individuals and organization are alike. Indeed, networks are characterized by cognitive diversity, consisting of a collection of cognitive anchors, that are built on experiences and fundamental concepts previously used to make sense of the environment (Bogner & Barr, 2000). Through these cognitive frameworks that interactively develop over time, individuals make sense of and act in their environments (Abelson, 1981).

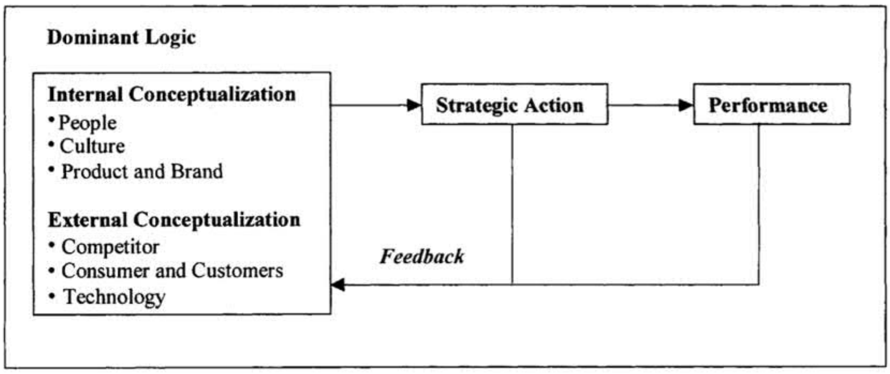

Figure 13. Elements of dominant logic and the link to performance (von Krogh et al. 2000)

Further developing detail on the cognitive domain, organizations are considered to incorporate a *dominant logic*, which has developed during the course of previous activities (Prahalad & Bettis, 1986; Bettis & Prahalad, 1995). In some organizations, the "bandwidth" of the dominant logic may be wider than in others, enabling better capabilities in coping with dynamic environments (Bettis & Prahalad, 1995; von Krough et al. 2000). According to von Krogh et al. (2000), dominant logic – that constitutes of both internal and external conceptualization (figure 13), functions as a lens or a filter for viewing the future and processing data, thus restricting and influencing the range of imaginable options (figure 14). This may in fact develop incapability to perform in changing environments (Bergman et al. 2017). As concrete examples on overcoming the limitations of the dominant logic and widening the bandwidth, Bettis and Prahalad (1995) suggest organizations to develop capabilities in strategic unlearning and learning to integrate new opportunities with the existing mental models. Even though the theory on dominant logic originates more specifically from research on managerial cognition (Prahalad & Bettis, 1986), the concept can be reasonably applied into the context of innovation adoption. This argument holds, as the pressure to innovate stems from both internal and external trajectories (Sundbo, 2002), while the adoption of innovations itself is dependent on sensemaking processes (Swan, 1995).

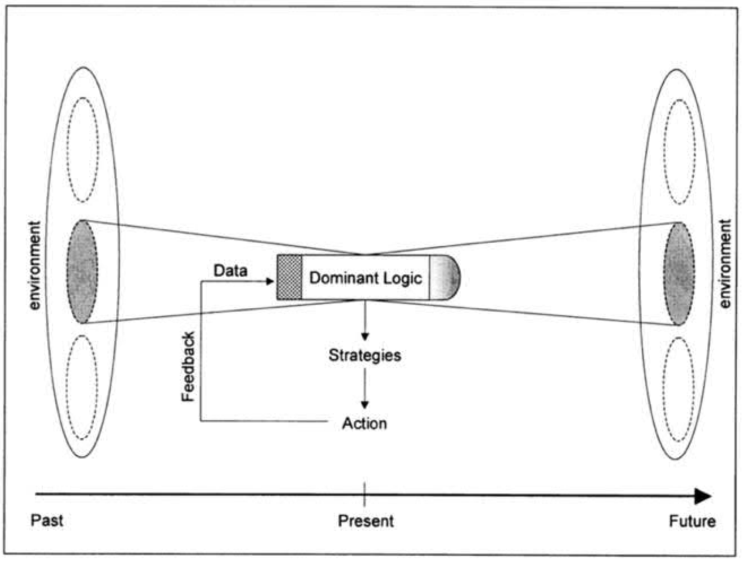

Figure 14. Snapshot of dominant logic as filter and lens (von Krogh et al. 2000)

Knowledge and shared cognition of ecosystem actors are fundamental preconditions for the emergence of ecosystems. By focusing their cognition towards converging future developments, the ecosystem actors may end up establishing triggering events for ecosystem emergence. (Almpanopoulou et al. 2017) More specifically, such shared cognition is understood as collective behaviour in organisations how they interpret their environment and act within it (Johnson, 2011). Through their research, Bergman et al. (2017) tentatively demonstrate that aggregated cognitive frameworks may in fact be utilized to describe and predict industry evolution during technological transitions. Furthermore, organizations and networks provide the appropriate platforms for establishing such shared cognition among groups of individuals (Bergman et al. 2015), establishing commonly accepted shared belief systems for coordinative activities and sensemaking (Ackermann et al. 2014).

Reflecting on the findings of this chapter, it could be argued that shared cognition among the actors of the socio-technical regimes is a fundamental component in the development of technological transitions. Even though diversity creates the seeds for development and innovation, change on a system level is characterized by a convergence of shared mental models (Bergman et al. 2017). Indeed, studies show that organizations tend to adopt the behaviour of other successful actors (Bogner &

Barr, 2000). This suggests that cognitive diversity is initially needed in order to trigger transformative activities, while shared cognition is a further requirement for solidifying the process. Yet, creative destruction prevails as an infinite loop that continuously develops systemic change as also indicated by the theory on technological transitions. This calls out for a strategic and analytical approach for introducing new technologies in established domains by composing shared cognition and focus towards the change among the ecosystem actors.

3.5.2. Motivation

Technology alone is not the goal for organizations or individuals. Motivation for adopting new technologies rather stems from an understanding of the benefits the technology can provide. (Vishwanath, 2009) As previously elaborated in this study, Rogers (2003) argues that adoption of innovations is dependent on relative advantage, compatibility, complexity, trialability, and observability. Indeed, these factors emphasize the benefits of a technology, thus facilitating sensemaking processes and widening the bandwidth of dominant logic. Moreover, convergence of motivation across ecosystem sides may be considered to develop openings for technological transitions.

Organizations formulate their motives for adopting new technologies explicitly or implicitly in their strategy, objectives, and culture. Furthermore, managerial understanding on the benefits of a technology is emphasized, as it increases the likelihood of allocation of the managerial, financial and technological resources needed for new implementations. In business context, technologies are often evaluated based on their perceived benefits for example in competitive advantage, information, efficiency, customer service, lead times, and access to new markets. (Bakar & Ahmed, 2015) Consequently, development of proof-of-concept, and business case demonstrations may be considered essential for organizational sensemaking processes on technologies.

On an individualistic level, motivation may arise from a myriad of variables that determine its orientation and intensity (Ryan & Deci, 2000). Self-determination theory provides a framework for understanding the reasons and goals that lead to action (Ryan & Deci, 1985). From this perspective, motivation is considered to stem from both intrinsic and extrinsic sources (Battistella & Nonino, 2012). First, intrinsic motivation refers to satisfaction that is not driven by external pressures or rewards, but rather the activity itself (Ryan & Deci, 2000). Thus, it describes the personal domain of motivation in both individual-driven, and social-driven dimensions (Battistella & Nonino, 2012). Second, extrinsic motivation stems from incentives and rewards (Ryan & Deci, 2000). This describes the domain of external stimuli for activities in terms of economic, professional, and social motivations (Battistella & Nonino, 2012).

Intrinsic motivations

Individual-driven motivations	**Social-driven motivations**
Entrepreneurial mind-set	Interesting objectives and intellectual stimulations
Opportunity to express individual creativity	Social responsibility, ideology, contribution to the greater good
Care for community, sense of membership, altruism	
Enjoyment, fun and entertainment	
Sense of efficacy, influencing	

Extrinsic motivations

Economic motivations	**Professional motivations**	**Social motivations**
Monetary rewards	Learning	Sense of obligation to contribute
Free products	Reputation	Social capital
Free services	Recognition	
	Reciprocity, establishing exchange relationships	

Table 6. Intrinsic and extrinsic motivation (adapted from Battistella & Nonino, 2012)

Overall, motivation is an important component in the development of technological transitions, as it provides meaning for activities. In order to motivate ecosystem participants to take action in adopting new technologies, a value proposition needs to be established. Simply put, the benefits of implementing a new technology must exceed the disadvantages and effort caused by the adoption exercise. After all, rational agents aim to maximize their utility in multiple dimensions. This is further emphasized in interorganizational networks characterized by direct and indirect externalities. Consequently, even if the efforts for technology adoption do not pay off right away, the activity may be rational and motivational in the perception of long-term returns and benefits.

3.5.3. Expectations

The concept of innovation is deeply rooted within a forward-looking philosophy. Indeed, human cognition has been suggested to be predictive by nature (Abelson, 1981). Hence, expectations are considered to incorporate an important role in the cognitive processes related to technological transitions. As previously discussed, perception on the future is an essential component in the establishment of motivation. Moreover, organizations construct and decode their environments through expectations and typifications, that set boundaries for incoming signals, and connect novel occurrences with familiarities (Patriotta & Gruber, 2015). Interestingly, expectations create twofold effects in organizations, as they provide a framework for daily practices, while also creating restrictions for sensemaking (Weick & Sutcliffe, 2007). More specifically, research suggests that restrictions develop through implicit expectations that are taken for granted over time, while explicitly formulated expectations can become sources of mindfulness and drivers for change (Patriotta & Gruber, 2015).

In the context of technologies, expectations are often overly inflated in the early phase of development (Jun, 2012). This pattern is described in a model known as the *technology hype cycle* (figure 15), that was originally created as a result of studies on emerging technologies conducted at Gartner (Fenn & Raskino, 2008). Due to its explanatory power, the model has become widely popular, while the empirical existence of the pattern has been demonstrated by studies focusing on various technologies (e.g. Järvenpää & Mäkinen, 2008; Jun, 2012). However, critique suggests that the hype cycle suffers from ambiguity in terms of juxtaposition of two discrete evolutionary models to create a single model, the equivocal definition of the dependent variable of visibility, and the unlikely generalizability of the expectation pattern for all stakeholders (Dedehayir & Steinert, 2016). Even though the hype cycle incorporates weaknesses as a theoretical model, through market research it may be considered to accurately reflect the mainstream perception on technologies, thus providing valuable insight into the cognitive aspects related to technological transitions.

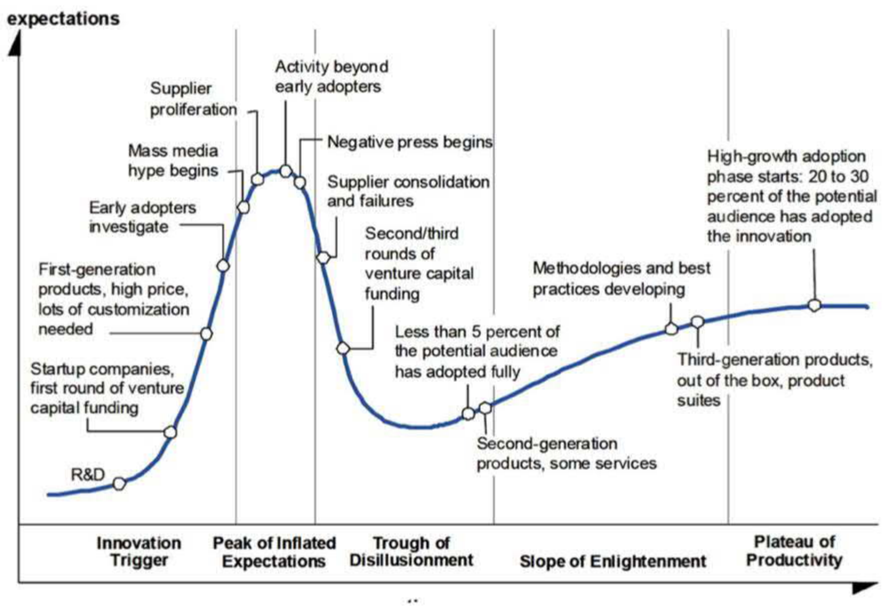

Figure 15. Gartner technology hype cycle (Fenn, 2010)

The hype cycle provides a perspective on technological transitions from within the established socio-technical regimes. In general, the model is used to explain the process of introducing technologies, how expectations are changed over time, and how the technology takes root in the market. Importantly, it identifies a pattern in which the impact of new transformational technologies is often overestimated in short-term, and underestimated in the long run. (Jun, 2012) Even though according to the original model, the transition path is rather fixed, research suggests that technologies are also capable of entering the plateau of productivity without experiencing inflated expectations (Dedehayir & Steinert, 2016). Indeed, this finding indicates that expectations and shared cognition on technological development may be managed. More specifically, even though explicitly formulated expectations build hype, it may be utilized for creating a bandwagon effect to build momentum for re-configuring the socio-technical domain. Moreover, management of expectations contributes to the establishment of shared cognition throughout entire ecosystems, emphasizing the importance of cooperative endeavours in innovation development.

3.5.4. Temporality

The seminal publication on the diffusion of innovations by Everett Rogers emphasizes the development of the diffusion process over time (Rogers, 2003). Indeed, temporality incorporates an important role in technological transitions, as such events do not materialize instantly (Geels, 2002; Geels & Schot, 2007). Consequently, it is essential to further elaborate how the timing of activities correlates with the creation of windows of opportunities for change.

A recent study by Granqvist and Gustafsson (2016) provides insights on how temporality of activities integrates with the process of institutional transformation. Their model on temporal institutional work (figure 16), refers to activities in constructing, navigating, and capitalizing on timing norms in attempts to change institutions. By establishing urgency and entraining activities with the rhythm of the surrounding institutions, actors may create windows of opportunities for even radical developments. More specifically, linking particular pressing interests and priorities with certain solutions, provides a baseline for an ideology of change that seeks to engage people in action. Importantly, a shared consensus on a temporally limited opportunity for change is developed by articulating openings in external timing norms, creating and enacting temporal boundaries for the transformation. At this stage, projecting radical visions and pacing the project is essential for building and maintaining momentum, until strong symbolic and material signals for progress are available to establish irreversibility of change. (Granqvist & Gustafsson, 2016)

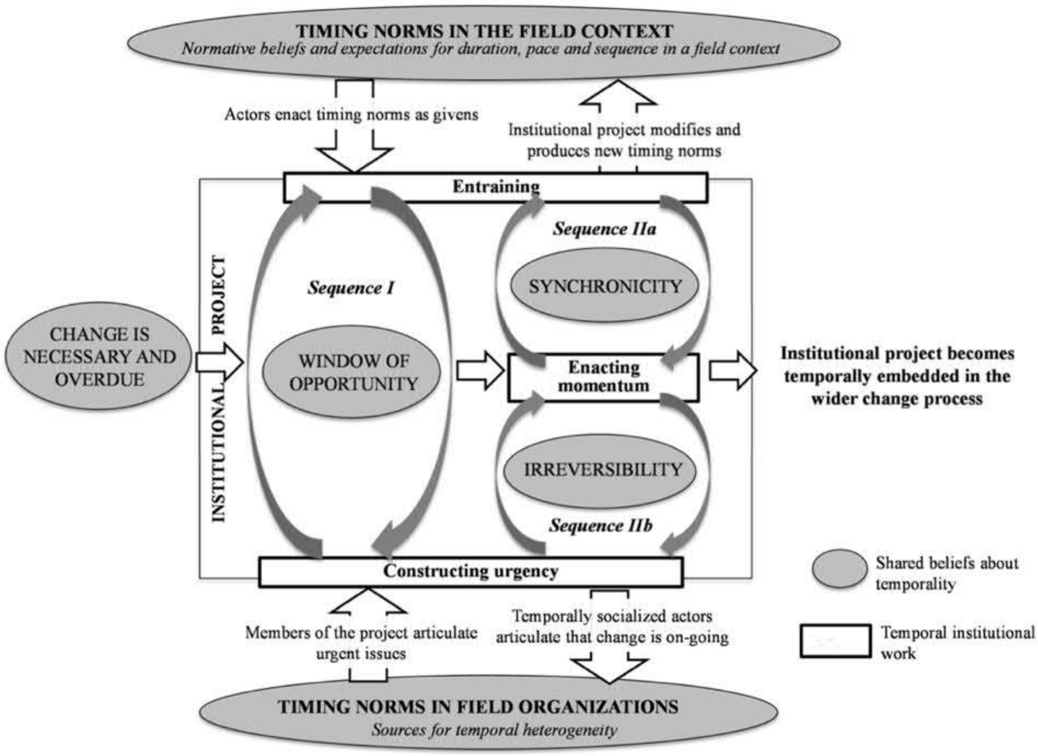

Figure 16. The model for temporal institutional work during institutional change (Granqvist & Gustafsson, 2016)

As previously discussed, technology that provides the means for organizations to function, exists embedded in its institutional environments (Garud et al. 2002). Temporal institutional work expands the framework of technology development by elaborating the importance of timing and engagement of relevant stakeholder groups. Indeed, technological transitions may be considered to occur as a result of collective and time-bound efforts to construct openings and boundaries for such events. In order to succeed in such endeavours, actors need to develop an understanding on the rhythm of the surrounding ecosystem to pace, synchronize, and enact activities throughout the socio-technical regimes in order to integrate new institutions to the system structure.

3.6. Theoretical framework

Synthesizing the findings of this chapter, a theoretical framework is constructed to elaborate the implications of emerging technologies in their surrounding business ecosystem structures. The framework is initially built on the seminal work by F. W. Geels (2002), which identifies the transformative implications of technologies in systemic structures. Moreover, components mediating the emergence of technological transitions are developed from existing academic literature on technology, innovation, business ecosystems, and managerial cognition. Because systemic transformations are complex non-linear processes (Geels, 2002; Adner & Kapoor, 2015; Ansari et al. 2016; Aarikka-Stenroos & Ritala, 2017; Dattée et al. 2017), the theoretical framework is rather presented as a canvas, than as a process model. The canvas is designed for mapping and analysing the key components and mechanisms through which emerging technologies interact with their surrounding environments.

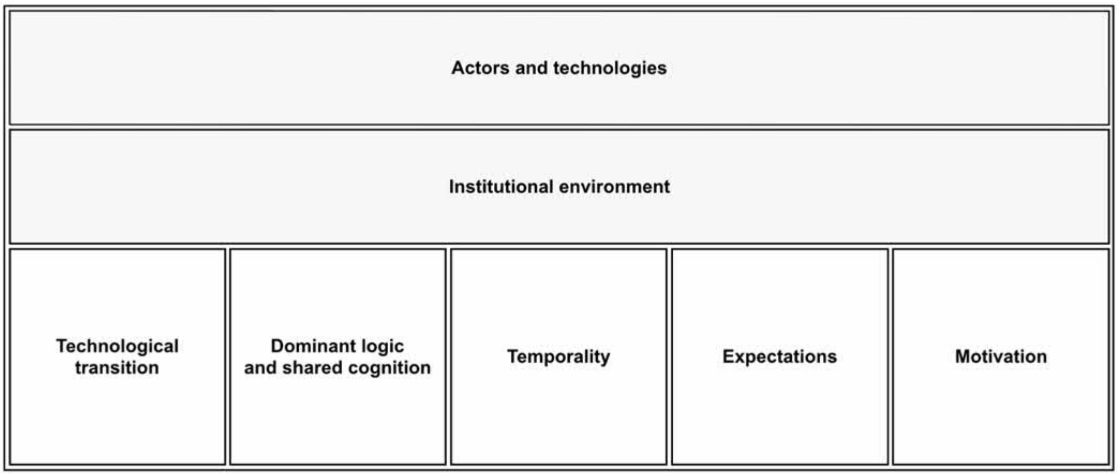

Figure 17. Theoretical framework canvas

A fundamental assumption of the theoretical framework rests on the business ecosystem literature, according to which organizations operate in complex network structures consisting of directly, indirectly, or loosely interconnected actors, technologies, and institutions (Adner, 2017; Aarikka-Stenroos & Ritala, 2017; Ansari et al. 2016; Dattée et al. 2017; Williamson & De Meyer, 2012; Moore, 1993). The framework establishes technology as an endogenous variable that re-arranges, and enables transformation processes through stochastic, continuous, and abstract events (Hatch, 1997, 130; Weick, 1990). Importantly, new technologies do not emerge in a vacuum. As an innovation is exposed to its external environment, interaction with the ongoing technological transition trajectories of the socio-technical regime may be anticipated (Geels, 2002; Geels & Schot, 2007). Moreover, the organizational domain incorporates a dominant logic for sensemaking processes that restricts and influences the range of imaginable options (Bettis & Prahalad, 1995; von Krough et al. 2000; Bergman et al. 2017), thus also mediating the implications of an emerging technology in its surrounding environments.

Activity and commitment on a new technology may converge based on the anticipations of the ecosystem stakeholders on the emerging value capture (Dattée et al. 2017). By focusing their cognition towards converging future developments, the ecosystem actors may end up establishing triggering events for ecosystem emergence (Almpanopoulou et al. 2017). Hence, anticipation on how inputs are, or should be turned into outputs may develop into a new form of shared cognition that disrupts the regime domain. Accordingly, motivation, expectations, and temporality provide the instruments for bridging the gap between the socio-technical regime and the emerging technology. Such development may cause tension or misalignment of rules, or on the contrary, loosen up to form a window of opportunity for the establishment of a new technology (Geels, 2002).

The following sub-questions can be utilized in attempts to reveal the key factors of the research context and phenomenon:

Institutional environment:	What are the key regulative, normative, and cognitive frameworks of the ecosystem structure?
Actors and technologies:	What are the core technologies of the ecosystem, and who controls these?
Technological transition:	What is the status quo of technological development in the surrounding ecosystem?

Dominant logic / Shared cognition:	How do the ecosystem actors perceive the existing organizational fields of the ecosystem?
Temporality:	Does the rhythm of the surrounding ecosystem development support the emergence of the new technology?
Expectations:	What are the expectations of the ecosystem actors on the emerging technology and industry development?
Motivation:	What are the drivers for engaging in exploratory activities and adopting the emerging technology?

4. Research design and process

Careful and well-founded selection of the research methods is an important part of the study, as it lays the grounds for meaningful interpretations on the researched phenomenon (Fisher, 2010). Together these selections of individual methods determine the methodology of the study (Olsen & Morgan, 2005). Following these principles, this chapter elaborates the design, development, and execution of the research process to uncover the methodological selections adopted in this thesis.

4.1. Research design

This study aims to understand the implications of emerging technologies in systemic development trajectories. Abstracting the complexity of the phenomenon of interest, the research questions are formulated based on a limited scope. As previously introduced in the chapter 1.3, the main problem of the study is established as:

1. *What are the implications of the blockchain technology in the development of the Finnish energy sector?*

For developing a detailed understanding on the phenomenon of interest, additional sub-questions are elaborated:

1.1. *How the blockchain technology can be applied in the energy sector*?

1.2. *What are the challenges for adopting the blockchain technology in the energy sector?*

These research questions are not only highly contemporary, but also reflect high uncertainty that requires multilateral examination. Hence, this study is conducted with an exploratory approach, which is identified as an appropriate strategy to establish a holistic comprehension of the phenomenon of interest (Saunders et al. 2009). More specifically, an empirical case study, grounded on the principles of qualitative research, is selected as a fundamental starting point for the research design. Instead of measuring observations by numerical means, qualitative research aims to explore the ambience and descriptions of the research domain (Berg, 2007). The selected approach is found adequate due to its strengths on enabling deeper understanding on complex phenomenon (Yin, 2009), such as encountered in this study. Overall, the qualitative methodology appropriately facilitates the research process with its capabilities in describing, understanding and explaining real-life events (Hirsjärvi et al. 2009, 152). In contrast to quantitative research, the selected qualitative approach may be considered to lack potential in creating generalizable results (Alasuutari, 2011, 203-206). However, such characteristics are not established in the objectives of this study.

Previous research on the specific topic of this study may be considered as extremely scarce. Due to the high level of novelty incorporated with the phenomenon of interest, the empirical research context can be considered as immature, whereas the possibilities for creating reliable and valid metrics are limited. The primary case study method, typically introducing “what?” and “how?” questions, is considered as an appropriate selection when addressing such novel and complex issues that are seen as challenging to study with quantitative methodologies (Yin, 2009). Importantly, the case study approach is able to provide insights to early phases of research on a subject (Eisenhardt, 1989), while enabling retention of a holistic and meaningful view on a real-life phenomenon (Yin, 2009).

Case studies are elaborated as either single -, or multiple case studies. This thesis adopts a single case study approach for addressing the specified research questions. The selection is adequate, as the research phenomenon is critical within the context environment selected for the study, representing a single industry. As a trade-off between the ability of a single case study to develop in-depth knowledge on the specified research questions, the approach suffers from ambiguity in terms of generalizing the results across alternative domains. (Yin, 2009) However, this is not a concern, as the objective of this study focuses on exploring the implications of emerging technologies in systemic development trajectories within specific boundaries defined in the main research question. Due to the single case study structure, elaborating the “case” itself becomes one of the most important elements of the research design (Yin, 2009). Consequently, this study introduces and extensive analysis on the key components of the main research question, identified as *“the blockchain technology”* and the *“development of the Finnish energy sector”.*

Grounded on qualitative research methodologies, this thesis adopts a mixed-method approach for exploring the case study by utilizing multiple different types of data. Such approach aims to combine the benefits of both qualitative and quantitative methods, while also creating value by indicating the independency of the results from a particular research method (Morgan, 2014). Importantly, the research process benefits from the mixed-method design, as it enables analysis on alternative aspects of the research problem and triangulation of findings (Saunders et al. 2009). Triangulation refers to the validation of the results by utilizing different independent data sources and research methods, aiming to mitigate the effects of the intrinsic weaknesses of the study, such as bias in the research data or analysis methods (Denzin, 1988).

Due to the significant methodological differences between qualitative and quantitative studies, Metsämuuronen (2011, 266) suggests defining a primary approach for the research when utilizing mixed-method techniques. Hence, the primary approach on exploring the research questions of this study is defined as qualitative, while quantitative data is utilized as a supportive data collection method. Yet, a problem exists on how to combine the results of the different methods (Morgan, 2014). In response to this deficiency, this study implements a content analysis method across the research data-set, to provide a common baseline for integrating the results into the research context.

Content analysis is a method that enables systematic and objective analysis of the research data. Importantly, it provides an effective tool for analysing unstructured data in a written format. The contents of the research data are described by identifying the meaning of the text, enabling formulation of conclusions on the research questions. As a result, the content analysis method enables quantification of qualitative verbal data. Firstly, the research data is consolidated by coding relevant data in the context of the study. Coding refers to keywords, that are used to indicate themes and objects of interest. In this sense, the researcher is able to decide which data is extracted from the material. For example, individual quotes from the text can be grouped under keywords that describe their contextual meaning. Secondly, clusters are formed from the coded data to further compress the contents. This may also reveal further internal correlation between themes extracted from the research data. Finally, theoretical implications and concepts are developed from the coded material. In other words, relevant information is extracted from the research data, from which theoretical concepts are created. Such methodology enables development of links between empirical research and theoretical concepts. (Tuomi & Sarajärvi, 2009, 108-113)

4.2. Data collection

This study incorporates data collected from multiple sources, such as seminars, interviews, and questionnaires. The dataset presented in the table 7 is categorized as both secondary, and primary research data, and can be described as multifaceted. Primary dataset refers to material collected based on the specifications defined by the researcher, whereas secondary data consists of independently produced open-source or privately shared material. Importantly, both data sources describe the dimensions of the case context, and qualify in terms of the theoretical framework.

This research data synthesizes two domains of knowledge; *(i) energy sector, and (ii) blockchain technology*. In order to take advantage of emerging research opportunities, the research data was collected as an iterative process of discretionary sampling combined with data analysis during the process itself (Eisenhardt, 1989). First, a collection of 17 pre-transcribed interviews with energy industry experts, focusing on the contemporary challenges of the industry development, was utilized. This data was collected in the DDI research project for a study published by Ritala et al. (2017)[1]. Enriching and refining the preliminary interview data, participation to seminars on energy sector development, featuring

[1] I express my gratitude towards prof. Paavo Ritala and prof. Kirsimarja Blomqvist for providing access to their research data collection.

some of the most innovative and experienced Finnish energy business professionals and academics, enabled a creation of a multidimensional, and well-saturated dataset on the energy sector domain. The other half of the secondary data, focusing on the blockchain technology, was initially collected from industry publications and seminars focusing on the state-of-the-art development of the technology and its applicability. All secondary data contents were transcribed to enable detailed content analysis.

Category	Type	Source	Description	Duration	Date	n
Primary	Interview	Fortum	Blockchain energy specialist	60 min	2.6.2017	1
Primary	Interview	VTT	Blockchain research scientist	67 min	16.6.2017	1
Primary	Interview	ETLA	Blockchain business expert	97 min	21.6.2017	1
Primary	Interview	VTT	Blockchain ecosystem expert	70 min	5.7.2017	1
Primary	Interview	Fingrid	TSO operations and smart grid expert	50 min	28.9.2017	1
Primary	Questionnaire	Reboot Finland D.Day Energy	Blockchain: Expectations on energy sector applications	-	13.6.2017	**15**
Primary	Questionnaire	DDI / SET / NEO-CARBON	Energy sector and blockchain word association exercise	-	22.2.2017	**8**
Secondary	Interview	DDI / Energy sector experts	Challenges of the Finnish energy sector development	42 - 109 min	2016-2017	**17**
Secondary	Keynote	Reboot Finland D.Day Energy	Jan Segerstam, Empower: Smart Flexible Energy Systems	9 min	13.6.2017	1
Secondary	Keynote	Reboot Finland D.Day Energy	Matti Vaattovaara, ABB: Making Grids Smarter	9 min	13.6.2017	1
Secondary	Keynote	Reboot Finland D.Day Energy	Pekka Sivonen, TEKES: The End Game - Finland in Platform Economy	8 min	13.6.2017	1
Secondary	Keynote	Reboot Finland D.Day Energy	Timo Seppälä, ETLA: Blockchain and the Energy Sector	10 min	13.6.2017	1
Secondary	Keynote	Fortum Digitalist Energy Forum	Pekka Lundmark, Fortum: Digitalization enabling the future energy system	31 min	11.5.2017	1
Secondary	Workshop	Reboot Finland D.Day Energy	Smart Flexible Energy Systems	60 min	13.6.2017	1
Secondary	Webinar	Leonardo Energy / UCL	David Shipworth, UCL: Peer to peer energy trading using blockchain	47 min	22.6.2017	1
Secondary	Keynote	TIEKE	Juha Viitala, Netgen: Blockchain	30 min	11.11.2016	1
Secondary	Expert Panel	EventHorizon 2017	Blockchain: What's in it for the Energy Sector	60 min	14.2.2017	1
Secondary	Keynote	BOND – Blockchains Boosting Finnish Industry	Ari Mutanen, Altoros Finland: Blockchain @ Altoros Finland	25 min	4.12.2017	1
Secondary	Keynote	BOND – Blockchains Boosting Finnish Industry	Timo Koskinen, IBM: Blockchain @ IBM	25 min	4.12.2017	1
Secondary	Keynote	BOND – Blockchains Boosting Finnish Industry	Elina Huttunen, SFS: Blockchain standardization	25 min	4.12.2017	1
Secondary	Keynote	BOND – Blockchains Boosting Finnish Industry	Kristiina Valtanen, VTT: Blockchain-enabled value creation	25 min	4.12.2017	1

Table 7. Research dataset

Secondly, based on the theoretical framework of this study, and preliminary analysis on the secondary research data, a semi-structured thematic interview guide was created and implemented for collecting insights from experts incorporating experience in both knowledge domains. The questions were then grouped into themes, while leaving space for open-ended conversation. This method was selected as it is the best interview type for studying "what" questions (Eriksson & Kovalainen, 2008). While maintaining flexibility, the selected interview method ensured a consistent understanding of the concept by all research participants (Hirsjärvi & Hurme, 2004), hence improving the reliability of the study. Such flexibility provided an essential contribution to creating knowledge on a complex and novel research phenomenon. All primary expert interviews were conducted either in person or via Skype, with durations ranging between 50 and 97 minutes. In order to further analyse the primary dataset, the discussions were recorded with permission, and transcribed into text format. By providing a promise of anonymity, the interviewees were encouraged to include their own personal thoughts and ideas into the interview. The following section provides an overview on the interviewees of the primary research data.

Interviewee 1 represents Venture Development department at Fortum. He has been tightly involved in use-case development projects on blockchain applications in the energy sector, and is hence referred to as a *"blockchain energy specialist".* More specifically, Fortum has been developing a pilot for utilizing blockchain technology in an electrical vehicle (EV) charging system.

Interviewee 2 is a scientist focusing on blockchain technology. In the past, he has also been involved in a blockchain project related to the energy sector. The interviewee has a background in mathematics and computer science, and is identified as a *"blockchain research scientist".*

Interviewee 3 is a researcher and an active developer of state-of-the-art blockchain literature. He has an extensive background in platform economies and global value chains. The interviewee is also a founding member in the blockchain use-case development project at Fortum, and is referred to as a *"blockchain business expert".*

Interviewee 4 is a manager of a comprehensive blockchain ecosystem development project at VTT, collaborating with many major Finnish industry actors. Consequently, the interviewee is considered as a *"blockchain ecosystem expert".*

Interviewee 5 is one of the founding members of the Datahub project at Fingrid, with 20 years of experience in the industry. In cooperation with the Ministry of Economic Affairs and Employment, he is currently managing the Smart Grid Vision Programme. Fingrid does not have active ventures in the blockchain domain but has indicated some interest in the technology. The interviewee is considered as an expert in *"TSO operations and smart grids"*.

Supporting the primary interview data, a questionnaire and a word association exercise were deployed during seminar participations, with an objective to further elaborate cognitive factors related to the research phenomenon. More specifically, the word association exercise was collected from professors and academics specialized in the energy ecosystem, whereas the questionnaire results were produced by a sample of seminar participants representing mostly energy business professionals. These supportive quantitative data collection methods were deployed mostly due to their benefits in collecting results from larger samples of research subjects during limited timeframes. The templates used in primary data collection are presented in the appendices 1-3.

4.3. Data analysis

This chapter provides a detailed description on the data analysis process applied in this thesis. To ensure the consistency of analysis across multiple data sources, content analysis is implemented as the main baseline for interpreting the research data. This method enables integration of the results of mixed-method research, while allowing a flexible approach for analysis.

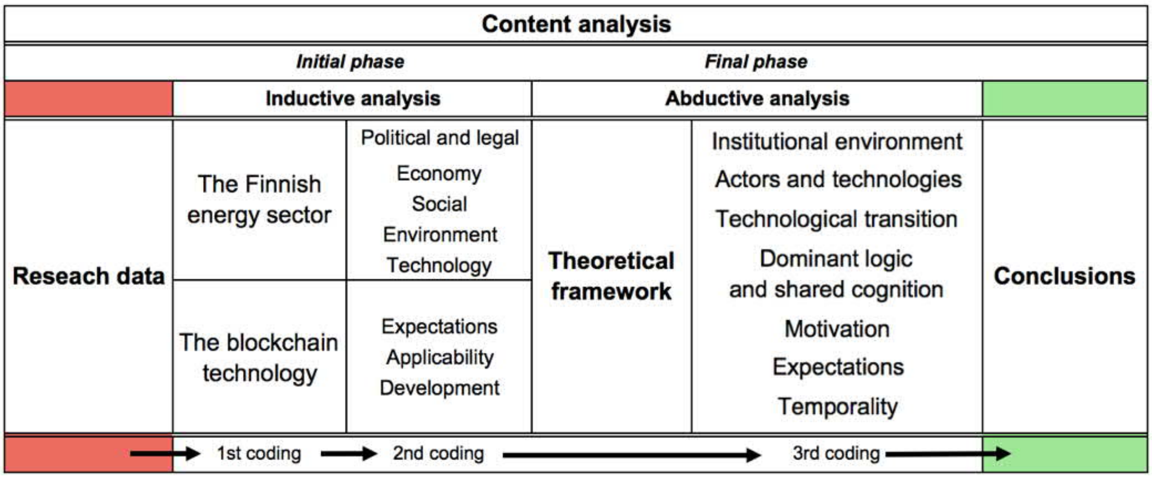

Figure 18. Summary of the data analysis process

The *initial phase* of the analysis process adopts an *inductive content analysis* model presented by Syrjäläinen (1994, 90), that enables a creation of holistic understanding on the entire research data-set:

1. *Researcher is exposed to the research material*
2. *Material is assimilated and theorized*
3. *Material is categorized into rough classes and themes*
4. *Research objectives and concepts are clarified*
5. *The frequency of observations and anomalies are verified*[2]
6. *Categories are cross-validated based on the research material*
7. *Conclusions are made*

A holistic understanding on the research context was considered as essential, due to the novelty and complexity associated with the phenomenon of interest. In addition, the inductive approach, that aims to build generalizations on particular phenomena based on the research material, prevented theoretical models from creating restrictions for the analysis (Alasuutari, 2011, 25). The research data was transcribed into a written format to enable coding and categorization of themes. Such method is considered as adequate, when the data-set consists of spoken language (Tuomi & Sarajärvi, 2009, 46-47). More specifically, a type of pattern

[2] Re-categorization of data is performed if necessary.

matching technique known as explanation building, was adopted for the analysis process. Explanation building aims to analyse the case study data by building an explanation about the case through an iterative process of identifying causal links about how or why something happened (Yin, 2009). The transcribed material was reviewed, and individual sentences or wider contexts were initially aggregated under two main categories:

1. *The Finnish energy sector*
2. *The blockchain technology*

A need for implementing more descriptive methods for data classification emerged from the process of explanation building. Firstly, PESTEL analysis was identified as an adequate approach for further categorizing the data on the Finnish energy sector. The analysis framework was selected due to its multifaceted approach for understand macro-environmental factors that impact the strategic orientation and development trajectories of organizations (Gupta, 2013; Yüksel, 2012). In other words, the PESTEL framework enabled a creation of a holistic view over the actors, technologies, and institutions of the Finnish energy sector. Six dimensions specified as, political (P), economic (E), social (S), technological (T), environmental (E), and legal (L) were identified (Cadle et al. 2010, 3-6) and applied for the coding process. In addition, a visualization of the energy sector was created based on the secondary research data to enable triangulation of results. Visualisation is often found useful in qualitative research, as it helps the researcher to simultaneously conceptualize and comprehend large data-sets and the relations between its components (Metsämuuronen, 2011, 257). This exercise was conducted by utilizing social network analysis tools as described in the Appendix 4.

Secondly, the evaluation of the research material on the blockchain technology began by analysing the collected questionnaire data. For questionnaire one, the average scores for the questions were calculated per respondent group. Results of the final open question were aggregated for later use. Then, all keywords created in the questionnaire two were qualitatively grouped into main categories describing the core technologies of the energy sector, previously defined as production, distribution, and consumption. Importantly, as the questionnaire required the respondents to develop keywords separately per energy sector and per blockchain technology in the energy sector context, the results were kept in their native sub-categories. Then, keywords were analysed across the sub-categories within each main category to uncover the patterns for the expected applicability of the blockchain technology in the energy sector. The analysis on the keyword correlations revealed three prominent themes. The findings of the questionnaires were then triangulated with the primary interview material, resulting in a creation of thee descriptive code categories *(expectations, applicability, and development)* for the blockchain technology in the context of the energy sector.

Induction alone may hinder the analysis process, as theoretical perspectives and concepts often help to understand the phenomenon. Indeed, the objective of this study is established as exploration of the phenomenon of interest within the boundaries defined in the theoretical framework. Consequently, *an abductive analysis method*, combining both inductive content based analysis and deductive theory based analysis (Tuomi & Sarajärvi, 2009, 95-99), was implemented in the *final phase* of the analysis process. More specifically, after the initial inductive analysis, the research material was re-evaluated against the main components of the theoretical framework. As a result, the conclusions of this study were developed from a combination of the emergent findings of the inductive analysis and the theoretical foundations of the study.

4.4. Reliability, validity and generalizability

In order to ensure high quality of the study, continuous evaluation of trustworthiness is essential throughout the research process (Eriksson & Kovalainen, 2008; Hirsjärvi & Hurme, 2004). More specifically, the concepts of reliability and validity become highly important (Hirsjärvi & Hurme, 2004). Reliability evaluates the replicability of the study, meaning that the study can be repeated with same results, when studying the same unit of analysis (Yin, 2009). In other words, reliability is considered to reflect the consistency of the research. In this study, reliability is ensured by carefully describing the research methodology and process in detail, thus enabling replication. However, as the researched phenomenon is still in its early phase of development, it is important to acknowledge that the results may in fact reflect temporality, thus continuing to develop over time.

In terms of ensuring validity, referring to the ability to measure what is supposed to be measured (Yin, 2009), the data collection and empirical analysis conducted in this study are guided by its theoretical framework grounded on existing research and literature on innovation, technology and organizational transformations. The validity of the theoretical framework can be considered as good, as it is carefully formulated by cross-analysing references, similarities, and confluences across multiple domains of related academic publications. This essentially reflects on the truthfulness of the arguments and conclusions proposed in this study, as their development processes can be rationally validated through peer-reviewed literature. Due to the complexity of the main research question, triangulation of data is utilized within the boundaries of the theoretical framework to enhance the validity of the study (Lee & Lings, 2008, 239). Such methodology is found adequate for mixed methods research, as it enables cross-validation of data across multiple sources and capturing alternative dimensions of the phenomenon of interest (Creswell, 2009). Indeed, high level of saturation could be identified between and within both the primary and secondary data-sets.

In addition to quality and trustworthiness, generalizability is established as a relevant evaluation criteria for research. This essentially indicates whether the research findings can be extended into a wider context (Eriksson & Kovalainen, 2008). It is important to emphasize that this study focuses on a limited case context. Thus, identical methodologies and coding of research data applied in this study are not directly generalizable to other cases involving different innovations and research environments. However, the theoretical framework of this study presents the research context on a high conceptual level. Hence, even though the objective of this study is not to create generalizable results, but to rather develop in-depth knowledge on a specific phenomenon, case specific adjustments could be applied to the research process in order to utilize the theoretical framework of this study in further scientific inquiries.

5. Empirical research

This chapter inductively elaborates the results of the empirical research conducted in this thesis. First, the case study itself is presented to provide an overview on the phenomenon of interest. Further developing detail on the description, the status quo of the Finnish energy sector is analysed, followed by a summary on the findings. Finally, more specific examples and value propositions are elaborated on how the blockchain technology can be utilized and developed in the energy sector. The findings of this chapter provide a baseline for further application and abductive discussion within the theoretical framework of this study.

5.1. Case study introduction

The Finnish energy sector is under disruptive pressure. Climate change, and the international commitment to mitigate its effects pushes the boundaries of innovation. Consequently, the share of renewable energy production is expected to grow significantly in the upcoming years. Despite of the active discussion and development activities, the actual wide-scale transition from fossil fuels into renewable energy ecosystems is still in its early phases. Moreover, the renewables incorporate fundamental issues in wide-scale usage due to uncertainty, variability and location-specificity of the energy production. Addressing these issues is essential, as due to the importance of energy as a commodity, supply and access must be secured at all times. As the intermittency of energy production increases, technologies that enable and facilitate balancing of supply and demand over time and across locations on a system level become paramount. Moreover, the developing energy ecosystem incorporates vast amounts of information that needs to be shared and coordinated among multiple stakeholders. This reveals a challenge in terms of industry integration. The current business paradigm emphasizes control over the ownership of data, resulting in a myriad of silos of data in multiple formats. In a fear of becoming underdogs in value creation, the owners of these data silos have little incentive to cooperate with each other.

Recently, a novel innovation known as the *blockchain technology* has developed a significant amount of interest and hype in the energy sector. It is a digital technology platform that enables and facilitates decentralized transactions and collaboration across networks of untrusted participants (see chapter 2). This is interesting especially in the context of the energy sector, as such technology presents a solution for enabling neutral coordination of market activities in an increasingly decentralized and saturated energy system. Significant funding and investments have been allocated in research and development on the blockchain technology. Multiple pilot projects have already tentatively demonstrated the potential of the blockchain in enabling automated two-way energy management and market activities in a novel and efficient way. However, instead of focusing on specific actors and blockchain solutions, the technology itself needs to be considered in the context of a technological transition: The implications of the blockchain technology in the development of the Finnish energy sector remain unexplored.

5.2. Energy ecosystem analysis

This chapter presents an in-depth analysis on the Finnish energy sector by triangulating the research data with two methodologies. More specifically, PESTEL -, and social network analysis (SNA) tools are implemented by following the principles of the content analysis process described in the chapter 4.3. The results provide a well-defined baseline for further discussion by identifying the actors, technologies, and institutions of the energy sector. Additional external references are utilized to refine the analysis.

5.2.1. Political and legal

Finland is a government led parliamentary democracy, characterized by one of the lowest rates of corruption in the world. Importantly, the Finnish constitution enforces freedom of speech, equality, and high standards for human rights. The political organization itself consists of multiple parties, whose members are chosen by public elections every four years, thus creating temporal pressure for national decision making. In terms of energy policy, the Ministry of Economic Affairs and Employment

(TEM) is responsible of preparation and design, whereas the government exercises decision making power. The Energy Authority (EA) is established as an organization that regulates and promotes the development of the energy markets, reduction of emission, energy efficiency and renewable energy usage (EA, 2017a). Due to the multiple party structure, policy making in Finland is often characterized as a compromise of different voices. Yet, the interview data suggests that energy policies in Finland are created and regulated by a relatively centralized group of homogeneous decision makers.

- *"Year ago, we had this internal project within a good team and we studied if we could use the blockchain technology to distribute renewable energy… One major challenge was this Finnish bureaucracy, so there are a lot of rules and laws… We didn't continue the project." (Interviewee 2, 2017)*

Finland is a part of the European Union (EU), thus incorporating a high political influence from EU directives that regulate the energy industry. In November 2016, the European Commission published an amendment to its Energy Efficiency Directive, that seeks to cut CO2 emissions by at least 40% by 2030 (European Commission, 2016). The EU has also implemented an objective to create an internal energy market. Consequently, more common legislation aiming to harmonize the European electricity market is expected during the upcoming years. Such objectives are reflected into local policy, setting the Finnish regulators under high pressure to implement supportive policies and initiatives for a transition towards renewable energy systems.

- *"The establishment of local energy communities across properties is possible in terms of current legislation only if the DSO gives a permission to build a cable between the end-points… The EU legislation is developing towards enabling the establishment of local energy communities." (Interviewee 5, 2017)*

The interview data presents a clear consensus on the high impact and importance of policy on the development of the Finnish energy sector. Even though the policy makers are indicating interest and ambition towards promoting the renewable energy transition, most of the experts criticize the speed of action, as decision making seems to be rather stagnant. This significantly reduces the possibilities to implement new services and markets. Further clarification is especially needed for rules and roles in local prosumer energy production, while incentives are urgently needed for promoting demand response participation and electric transportation. Yet, great initiatives are also in progress. For example, TEM has implemented a development programme on Finnish smart grids in cooperation with the Energy Authority and the national transmission system operator (TSO) Fingrid. The objective of the programme is to establish a common vision on the future of the Finnish electricity system and to present solutions for enabling the emergence of smart and distributed service platforms (TEM, 2016).

5.2.2. Economy

The economic structure of Finland has an emphasis on heavy industries such as forestry, paper, and pulp. These industry actors are responsible of a major part of the total energy consumption. This is reflected into national energy policies, which tend to favour bioenergy generated by burning wood. Consequently, a centralized group of industry actors possess major influence in politics and legislation through lobbying. Importantly, the Finnish economy is also technology oriented. Domestic companies are considered to incorporate high level of social capital and technological knowledge.

The Finnish energy system is characterized by high level of natural inertia for change due to economics. The energy system has been initially built around large production facilities that incorporate significant long-term investments. Even though electricity production has become increasingly decentralized, the economic renewal cycle of the infrastructure is rather long, as the payback time for capital is typically around 35-40 years. In addition, the combination of the current low price of electricity with the high unit cost for enabling distributed renewable energy production, causes significant reluctance for further investments in vRE production.

- *“Energy is so cheap and the margins are so small that companies need to start move towards energy service business. The consumers are starting to have electric vehicles, solar panels, and storages, so this all has to be somehow arranged to make it work easily.” (Interviewee 5, 2017)*

Finland is a part of the joint Nordic electricity market, which is subject to free competition within its regulatory framework. The wholesale of electricity is highly centralized around Nord Pool, that provides both day-ahead (Elspot) and intraday (Elbas) markets, while financial products are auctioned by Nasdaq OMX Commodities (Spodniak et al. 2016). Large industry actors purchase their supply directly from the producer, whereas private consumers typically subscribe to products offered by various retailers. The market itself can be described as a relatively linear supply chain, as most of the end-users participate simply by purchasing electricity without further activities in trading. Simply put, most consumers have traditionally been content just with “paying the bills and lights staying on”. Whereas the private -, and service sector combined cover just over half of the national energy consumption, they constitute two thirds of the total peak load demand (Fingrid, 2017a). This establishes significant business opportunities in load balance management.

In terms of production, retail, and energy services, Fortum Oyj possesses significant market influence, even though many other companies also participate in the markets, especially in retailing. Transmission side of the energy ecosystem is a natural monopoly. The national power grid is operated and maintained by a TSO company Fingrid Oyj, through which 77 percent of all electricity consumed in Finland is transferred (Fingrid, 2017b). In addition, the local distribution of electricity is dependent on regional distribution system operator (DSO) monopolies. This is considered as a significant barrier for the development of the energy sector.

- *“Before prosumerization of energy will start sort of a happening we need to solve the problem of the local distribution monopolies.” (Interviewee 3, 2017)*

- *"The DSOs cannot be considered as neutral actors. They are mostly bound to the retailers and producers of energy as a part of the same corporation... TSO operations on the other hand are tightly regulated." (Interviewee 5, 2017)*

By participating in the Nordic markets, Finland both imports and export electricity. Negative trade balance can be observed from time series data provided by Fingrid (figure 19). The price level of electricity is rather low, due to a relatively high level of renewables, characterized by near-zero marginal cost production. This on the other hand reduces incentives for investments. The price of electricity itself, which is based on the transferred quantity, consists of a transfer price, sales price, electricity tax, and value-added tax (EA, 2017b). In accordance to EU directive 2003/96/EY, the Finnish government collects tax from electricity products, that includes both tax and a strategic stockpile fee, constituting 0,02253 EUR/kWh in general class 1, and 0,00703 EUR/kWh in class 2 which applied only for industry and data centre usage (Vero, 2017). Accountable taxpayers are indicated in the Finnish law (Law on taxation of electricity and certain fuels, 30.12.1996/1260, 5 §). As the electricity tax is an indirect excise tax, it is essentially applied into consumption (Juusela & Jovio, 2017).

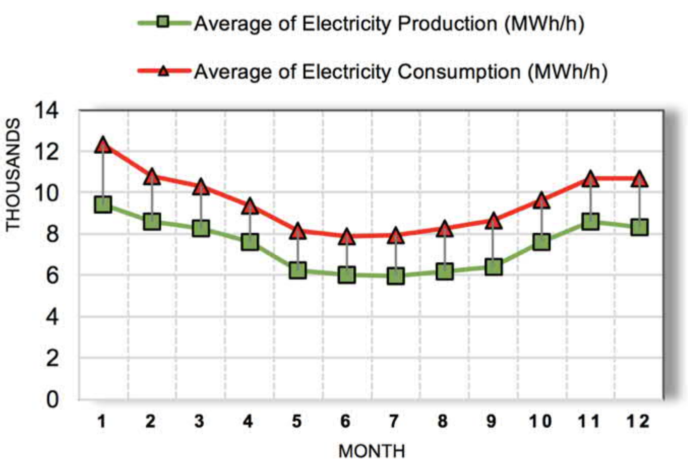

Figure 19. Average domestic electricity production and consumption in 2016 (Fingrid, 2017c)

Research data suggests that economic incentives and new pricing mechanisms are needed for establishing a truly two-way electrical market. For example, the current market model rewards battery discharging to the grid only with a sales price.

However, if the battery owner decides to buy back some of the electricity, the price is higher due to additional price components as previously elaborated. Also, the discharging process of batteries is comparable to selling energy and is thus a subject for taxation. This inequality in the pricing mechanism causes reluctance to participate in load balancing and demand response. Overall, the economic incentive to participate in the energy markets is rather small for average consumers.

Taxation is considered as one of the barriers for energy ecosystem development. Rather than applying a fixed tax per kWh, it has been suggested that the tax should rather be a percentage of wholesale price. While the price of electricity is determined in the markets, the current fixed tax model does not reflect to this price variability, thus decreasing incentives to temporally allocate consumption. However, as the taxation of electricity is initially regulated in the EU directive 2003/96/EY, that sets a minimum tax per consumption, the applicability of such price based tax is questionable. For this reason, as a part of their Smart Grid Vision Programme, TEM has commissioned law firm Borenius to investigate whether price based electricity taxation would be possible within the framework of EU regulation (TEM, 2016). Their report concludes that even though the initial starting point for the directive 2003/96/EY is based on quantity, it does not prohibit price based taxation as long as the minimum tax level set by the directive is fulfilled, and that this type of taxation does not appear to conflict with current directive on VAT (Juusela & Jovio, 2017). Furthermore, the Ministry of Finance has agreed to develop a concept model for tax-free energy storage, which is highly needed in order to transition towards a flexible and smart energy system where storage is essential.

5.2.3. Environment

Geographically Finland is a rather remote location on the northern hemisphere. The winters are long and dark, and summers short but relatively sunny. This highly affects the national capabilities of implementing vRE energy sources, such as PV and wind. One of the interviewees described this as a “February problem”, referring to a cold and dark climate with not much wind. Consequently, the importance of energy storage and demand response mechanisms are considered as essential for the future of the Finnish energy ecosystem. The national electricity grid is connected to its neighbouring countries (figure 20), enabling access to wider markets.

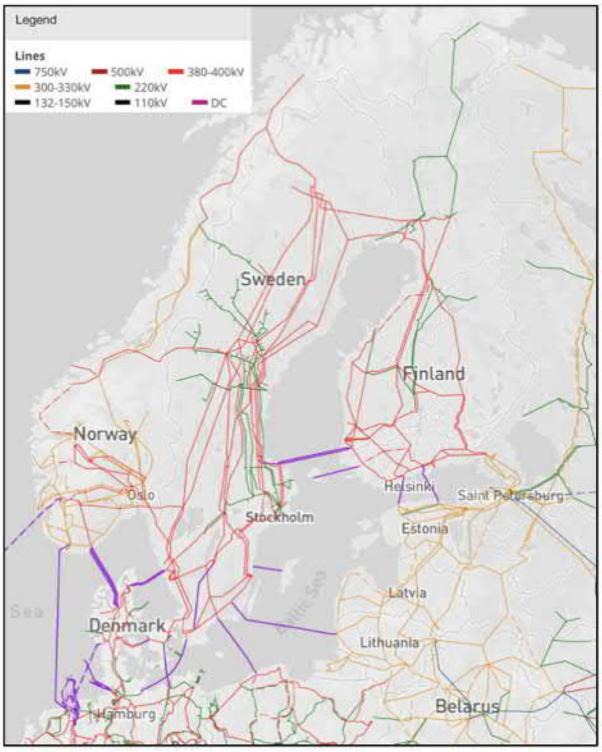

Figure 20. Nordic TSO electricity grids (ENTSO-E, 2017)

Environmental concerns have developed into the daily discourse of the Finnish societal domains. This can be observed from the national commitment on preventing the development of the climate change. The interview material identifies the desire for a cleaner energy structure as a facilitator of shared vision and collaboration in the energy sector. Yet, conflicting interests towards intermittent energy production arise from heavy industries reliant on energy in large quantity and steady supply. So far, Finland has been opting for increasing its nuclear energy capacity and developing its bio-energy infrastructure that provide relatively emissionless and highly controllable production.

In terms of environmental effects, Finland's orientation towards bio-energy incorporates significant long-term risks. The research data clearly indicates a concern on the CO2 and NOX emissions caused by the burning of wood and other biomaterials. Indeed, wood-based energy is not considered as totally CO2 neutral energy production. One of the experts described this dependency on wood as a "carbon bubble", which is likely to burst if the EU decides to change course on its bio-energy policy. This threat is highly relevant, as the EU policy aims for carbon free production. In addition, the disadvantages of nuclear energy are widely recognized in terms of the final placement of residual nuclear waste, and the hazards of catastrophic failures in the power plants causing major environmental risks.

5.2.4. Social

Finland is a country of high standards in education and social capital. The country is known for its technology orientation and a state-of-the-art university system. Especially IT and ICT experts are highly valued by professional markets. These characteristics effectively attract foreign workers and students to pursue their career in Finland, further enriching the variety and level of social capital available.

The importance of understanding and mitigating the risks of the climate change has become a daily topic amongst the public. People are increasingly becoming interested in energy efficiency and electricity market participation. For example, investments to electrical heat pumps have recently been widely popular. Private persons are also installing small scale electricity production capacity and storage in their properties. Consequently, the country is about to slowly witness a rise of a prosumer culture. As electricity production becomes more and more localized, creation of regional energy cooperatives is expected, in which prosumers trade electricity directly with their neighbours. Yet, mostly due to the lack of incentives and commercial solutions for actual market participation, electricity may be considered as a rather abstract product. Indeed, private consumption behaviour is rather driven by environmental and social causes. Supported by the prevalent megatrends such as urbanization and digitalization, combining the intrinsic motivation of consumers with monetary incentives, creates new kind of opportunities for companies to create customer relationships and business models.

- *“We are naturally seeing this shift of production away from centralization, big central mega producers towards neighbours, peers and behind the meter… I mean that's happening largely due to a big release and rapid reduction in the cost of PV and storage. It's also people are becoming more and more aware of the inefficiencies the energy system and they're becoming more conscious, and have this greater desire for local clean production.” (Interviewee 1, 2017)*

- *For the first time in world history, the consumer is starting to have a choice in electricity production, and things. They can become more independent.” (Interviewee 5, 2017)*

Even though energy efficiency has become an increasingly important part of people’s lives, an average person is rather reluctant towards participating in active energy management. This is understandable, as people typically have a myriad of other issues, tasks, and activities to be managed on daily basis. Consequently, automation and efficiency services for energy management are increasing their public demand. Even though companies are starting to introduce services and products for demand response and home automation, the incentives for average consumers to participate are rather limited, due to dominant market mechanisms.

5.2.5. Technology

The electrical grid is the technological backbone of the modern society. In this context, Finland relies heavily on nuclear, hydro, and bio energy. Nearly one third of electricity is produced as combined heat and power (CHP) generation. (Finnish Energy, 2016) These production methods are highly controllable and predictable. Whereas hydro power is environmentally friendly, it incorporates natural limitations for scalability due to geography. The low level of national PV implementation can be observed from the figure 21 by its absence. However, mainly due to technological development and wide support for renewable energy, the production structure of the Finnish energy system is becoming increasingly intermittent. Whereas controllability of production diminishes, the adjustment capabilities of consumption must increase in order to secure the stability of the grid, as it is critical that production and consumption are in balance at all times (Fingrid, 2017a). This establishes significant technological development challenges for the energy system.

In the Reboot Finland Energy seminar, Jan Segerstam of Empower described that the current energy system in place has been designed into a world that is not here anymore. As we continue to ramp down the fossil based energy production in favour of renewables characterized by intermittency and systemic complexity, more efficient resource allocation, management and communication technologies are required. Thus, the modern energy supply chain needs to become increasingly non-linear and interactive, as digital technologies are expanding the peripheries of ecosystems, and democratizing knowledge and market information. From a technological perspective, this development entails a systemic change from a centralized structure towards distributed networks.

- *"One of the obvious largest themes is, the energy sector is going from being a very centralized system to being decentralized… How to accommodate for a more decentralized electricity system in the future?" (Interviewee 1, 2017)*

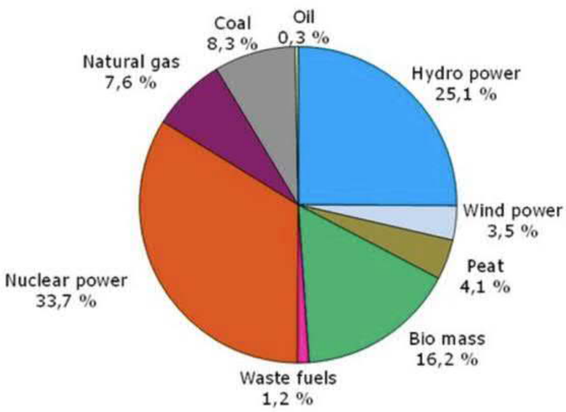

Figure 21. Electricity production by energy sources 2015 (Finnish Energy, 2016)

In terms of technology, the Finnish electricity system is rather smart already. Supported by national policy, Finland has implemented AMR (automatic meter reading) electricity meters in practically every household and building. This enables near real-time remote measurement of production and consumption. Consequently, the establishment of smart grids that provide interactive service platforms for the future energy ecosystem is emphasized in the contemporary technology discourse. On international level, Finland can be currently considered as forerunner in smart energy technologies.

- *"Technology is the driver of change. The prices are becoming increasingly lower, and that is the driving force. The energy sector actors need to adapt to that." (Interviewee 5, 2017)*

Digitalization is an antecedent for enabling novel energy services in an increasingly complex and interactive energy system. Accessing and managing real-time data is essential for the development of future competitive advantage. Competence and technology for real-time measurements and data collection is widely available, but issues arise from the management perspective on how to establish a common platform for the future energy ecosystem. In addition, the research data suggests that the current market mechanisms and the lack of incentives are creating barriers for technology adoption.

Along its current development path, Finland is moving towards a centralized solution for energy data management. The national TSO Fingrid is developing a database known as *"the Datahub",* which will be utilized as a central database for all market data, accessible by all market players. This approach aims to streamline and enhance market communication and data sharing across organizational borders. (Fingrid, 2017d) As for now, the Datahub will facilitate only historical data, but discussions and analysis for the need of a real-time Datahub have been initiated. However, as previously discussed in this study, such centralized platform architecture entails risks in terms of data and transaction integrity, while also developing reluctance for ecosystem participation due to asymmetrical power relations.

5.2.6. Status quo of the Finnish energy sector

Concluding the PESTEL analysis, it is fair to argue that the Finnish energy sector is in a midst of a change. This transformation overarches each of the analysed domains unambiguously. Such pressure is mainly considered to originate from three sources: Firstly, climate change prevention is being actively emphasized in international policies, further reflecting into local decision making and business activities. Secondly, technological development of the energy industry has been identified as a significant driver of change. Thirdly, consumer behaviour is changing, as the adoption rate of digital technologies increases. These trends create new requirements for executing business models and strategies in the energy sector. Overall, multiple contemporary ecosystem stakeholders with important roles in the developing energy ecosystem, can be identified from the research data (table 8).

Function	Entity	Example
Consume	Private end-user	Private person
Consume	Industrial end-user	Stora Enso
Distribute	Transmission System Operator (TSO)	Fingrid
Distribute	Distribution System Operator (DSO)	Caruna
Distribute	Market Operator	Nord Pool
Distribute	Retailer	Helen
Produce	Producer	Fortum
Regulate	Local policy maker	TEM
Regulate	Global policy maker	EU

Table 8. Abstraction of the contemporary Finnish energy ecosystem stakeholders

The contemporary discourse in the energy sector can also be visually observed and summarized through a social network analysis (SNA) applied on the transcribed secondary interview material. The results are presented in the figure 22, while details and replication steps on the SNA exercise are provided in the appendix 4. Interestingly, the analysis reveals clusters of highly interconnected concepts and keywords. Yet, it is important to acknowledge that even though articles and irrelevant words were initially removed from the original string of text, the applied identification and filtering processes of the keywords tend to emphasize natural compound words, as only *n* and *n+1* words were considered while building relations. Consequently, the validity of insights on indirect causalities between keywords may be questioned. However, this deficit is overcome by triangulating the SNA with the PESTEL analysis.

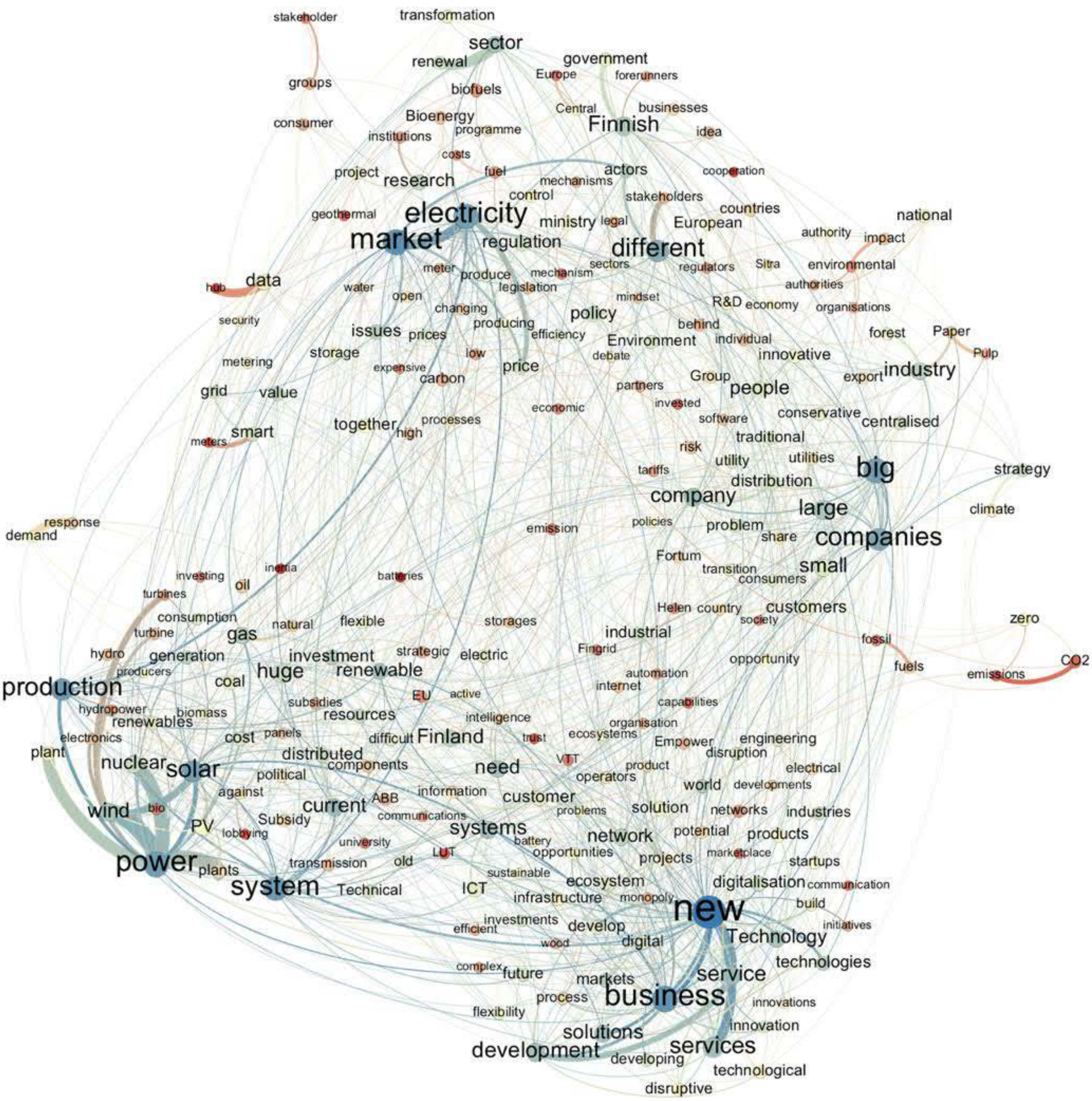

Figure 22. Finnish energy ecosystem visualization

Similarities can be observed with the content based PESTEL analysis. The clusters demonstrate that keywords related to new digital energy business models and innovations are detached from the dominant electricity markets, which are highly connected with industry incumbents, bioenergy, and various political and legal keywords. Indeed, regulation seems to incorporate a close position to the cluster of electricity market. Yet, disruptive forces are present in the ecosystem. Industry incumbents are being exposed to new business opportunities found in digital technologies and energy services, mostly connecting with renewable energy sources and distribution of resources. Overall, the ecosystem visualization tentatively anticipates turbulent future for the Finnish energy sector. As of now, the ecosystem sides are relatively detached from each other, and only time will tell whether the clusters begin to converge.

5.3. Emerging blockchain applications in the energy sector

As a result of extensive media coverage and public discussion, the blockchain technology has become a fad that holds a promise on increased competitive advantage and value creation opportunities. However, a recently updated Gartner research suggests that the early excitement has calmed down to some extent, and businesses are slowly beginning to understand the truly beneficial applications for the blockchain (Gartner, 2017b). Indeed, the interview material of this study clearly elaborates that many incumbent technologies often provide more efficient and robust solutions to existing business problems, and the blockchain should be considered as a purpose specific tool. Yet, due to the ever-developing complexity of the energy business, many visionaries with a profound understanding in the contemporary energy sector development have identified the blockchain as an important innovation.

- “My humble opinion is that 2015 was the break point. It (blockchain) had been developing behind there, but then there was this bigger consortium that started to work and they started to make the blockchain then more publicly known. Then it was mentioned in the media and then companies started to dig into that… It's not anymore some shady nerd technology.” (Interviewee 4, 2017)

#	Question	Average
	Business	
1	Knowledge on energy sector	4,20
2	Knowledge on blockchain technology	2,80
3	Blockchain is an important technology in the renewable energy sector transformation	3,70
4	During the next 5-10 years, I expect the blockchain technology to cause major changes in the way we produce and consume energy	3,30
5	Meeting these expectations is realistic and extremely probable	3,40
	Government	
1	Knowledge on energy sector	4,00
2	Knowledge on blockchain technology	2,50
3	Blockchain is an important technology in the renewable energy sector transformation	3,50
4	During the next 5-10 years, I expect the blockchain technology to cause major changes in the way we produce and consume energy	3,00
5	Meeting these expectations is realistic and extremely probable	3,50
	Research	
1	Knowledge on energy sector	3,67
2	Knowledge on blockchain technology	3,33
3	Blockchain is an important technology in the renewable energy sector transformation	3,33
4	During the next 5-10 years, I expect the blockchain technology to cause major changes in the way we produce and consume energy	3,67
5	Meeting these expectations is realistic and extremely probable	2,67
	Total	
1	Knowledge on energy sector	**4,07**
2	Knowledge on blockchain technology	**2,87**
3	Blockchain is an important technology in the renewable energy sector transformation	**3,60**
4	During the next 5-10 years, I expect the blockchain technology to cause major changes in the way we produce and consume energy	**3,33**
5	Meeting these expectations is realistic and extremely probable	**3,27**
		n = 15

Table 9. Questionnaire 1 results per respondent category

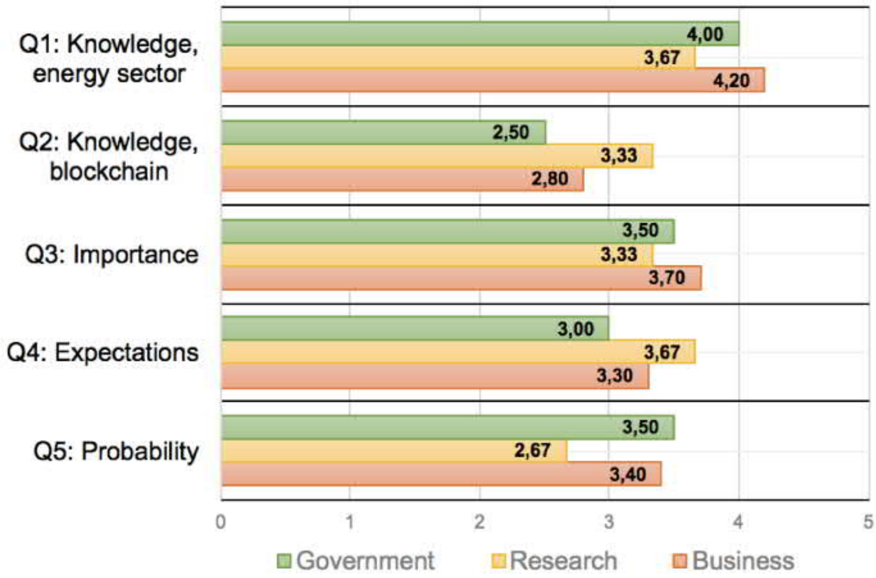

Figure 23. Questionnaire 1 results visualization per respondent category

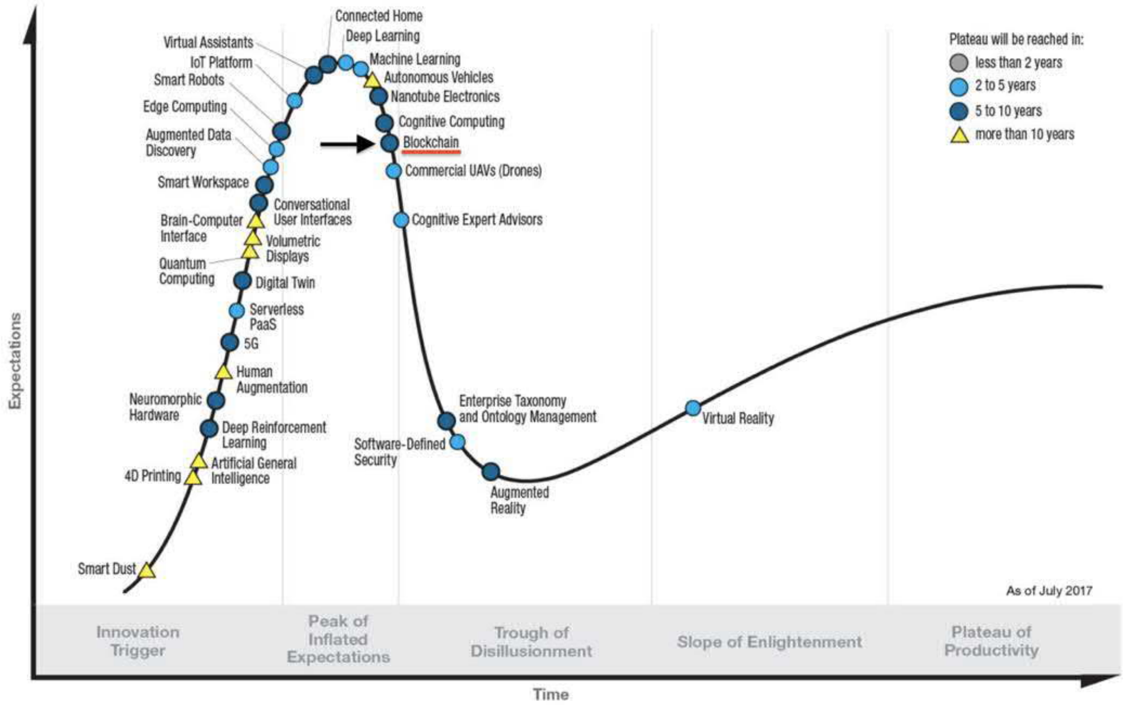

Figure 24. Gartner hype cycle for emerging technologies 2017 (Gartner, 2017b)

The results of the questionnaire 1 on the expectations regarding the usage of the blockchain technology in the energy sector (table 9) are somewhat in line with Gartner research (figure 24). The expectations on the impact of the innovation on the development of the industry are consistently higher than the level of understanding on the technology itself. Indeed, the expectations are slightly above average of the measurement scale. As for the respondent classification groups, the business and government representatives are clearly positioned lower in terms of blockchain knowledge than the researchers, but possess higher knowledge in the energy industry. Interestingly, the researchers adopt a slightly more conservative stance in terms of estimating probability, but indicate higher expectations for the disruptive effects of the blockchain technology in the energy sector. Furthermore, the potential use-cases identified for the blockchain in the energy sector are highly similar with each other in terms of enabling novel energy market arrangements and system automation.

Respondent Type	**Application**
Business	Demand response tech like batteries P2P electricity market P2P trading Prosumer enablement (micro grids) Re-selling energy P2P
Government	Automatic smart contracts Off grid
Research	Demand response Energy exchange in micro grids in local level EV charging

n = 10/15

Table 10. Questionnaire 1 results on the identified blockchain energy sector use-cases

The questionnaire 2 presents a word association exercise on the core technologies of the energy sector, and the blockchain technology. The sample of respondents represents academics focusing on energy sector research. The respondents evaluate their own general familiarity in the energy sector and the blockchain technology as indicated in the table 11. The results in table 12 reveal correlations between the two context categories. Overall, 57 keywords are identified in relation to the current and developing energy sector, whereas 41 keywords describe the expected applicability of the blockchain technology in the energy context.

#	Familiarity with the Finnish energy sector (1-5)	Familiarity with the blockchain technology (1-5)
1	3	3
2	3	3
3	5	1
4	4	2
5	2	2
6	4	2
7	5	3
8	4	3
Avg.	**3,75**	**2,38**

Table 11. Questionnaire 2 respondent familiarity in the research context

Table 12 presents the keywords developed in the questionnaire 2. These individual words are coded according to the three dimensions of the energy ecosystem, as previously defined in this study (*production, distribution, consumption*). In accordance to content based analysis methodology, contextual correlation can be identified across the energy sector, and blockchain related keywords within the code categories. These correlations are highlighted and bolded. Based on the analysis, three specific themes are identified and presented in the header row of the table. Finally, the most prominent themes are identified as *"control and automation" (1,18)*, and *"end-user flexibility and autonomy" (1,0),* based on a ratio between correlating blockchain -, and energy sector keywords. Overall, the analysis provides insight to the cognition on the applicability of the blockchain technology in the energy sector.

Blockchain/Energy Keyword Ratio: **0,38**		Blockchain/Energy Keyword Ratio: **1,18**		Blockchain/Energy Keyword Ratio: **1,0**	
Theme: Distributed production of renewables		**Theme: Control and automation**		**Theme: End-user flexibility and autonomy**	
Production		**Distribution**		**Consumption**	
Energy	**Blockchain**	**Energy**	**Blockchain**	**Energy**	**Blockchain**
Nuclear power and risks	**Bioenergy**	Centralized systems	**Self-steering networks**	Consumption	Emergence
Nuclear waste and risks	**Solar energy**	**Energy transfer costs**	**Storage of electricity?**	Negawatts	**Applications for household electricity**
Thermal power plants	**Windmills**	Geopolitical dependencies	**Resilience**	**End-user apps**	**Roaming in energy**
Big energy players	**Geothermal heating**	**Smart meters**	Energy sales	Spot	Diversity
Carbon dependency	**Prosumption of energy**	**Demand response**	**Consumer-to-consumer transmission**	**Demand**	**Demand peaks?**
Global warming	**Prosumption**	**Microgrids**	**Energy distribution**	Peak	Contracting
Not sustainable	Unpredicted	**Smart meters**	**Smart metering applications**	**Electrical vehicles**	**Behind the meter**
Power plants		**Demand side management**	**Peer to peer trading**	Combustion engine	**Demand**
Biomass		**Smart grid**	Getting rid of retailers	**Intelligent home**	**IoT**
Nuclear power		**Storage**	**Ensure security of supply**	**Electrical vehicles**	
Solar power		**Power transmission**	**Reliability**	**Intelligent charging**	
Wind power		**Control algorithm**	**Datahub**		
Micro generation		**Battery technology**	Market		
PV		**AMR**	**Flexible**		
Renewables		**Datahub**	**Storage**		
Wind power		**Battery**	**Shifting**		
Solar panels		**Smart grid**	Internet		
Distributed generation		DC-distribution	**Electricity micro-trading**		
Intermittent generation		Power conversion	**Peer-to-peer electricity**		
Distributed production		**Energy storages**	**Demand response**		
Renewable energy		**Electricity network**	**Safety**		
Forecast			New business models		
Solar PV			**Energy as a currency**		
Wind			**Intelligent metering**		
Distributed production			**Shared resources**		

Table 12. Questionnaire 2 results and analysis

Developing from the questionnaire results presented above, the next subchapters present two use-case descriptions for the blockchain in the energy sector. In order to establish a profound understanding on the applicability of the innovation, secondary research data is utilized to triangulate correlations with the primary interview material. Importantly, understanding the application potential of the technology is essential for further analysis on its implications in the energy ecosystem development.

5.3.1. Bilateral electricity trading

A housing society can be taken as an example on how sharing of electricity can be arranged as a peer-to-peer system. In this type of micro grid, the housing society is able to reduce its dependency on the national power grid, by autonomously allocating energy generation, distribution and consumption internally. The community has only a single point of connection to the external power grid, which is used only when the internal sufficiency of the community is not enough to meet the demand requirements. Due to its fundamental characteristics, the blockchain is considered as an optimal technology platform for mitigating transaction costs and bypassing vertical IT-ecosystem silos by enabling direct and universal communication between the end-points of the network. (Mattila et al. 2016a)

- *"If you look at the blockchain in the energy sector there's two key areas that its going into. One is sort of facilitating bilateral trades, so currently if you have trades, there's lots of brokers and middlemen in between and that makes the marginal cost very high. And you have the cost of electricity coming down and falling all the time. That's making energy trading a very tough business to make a margin in. So, the blockchain facilitates a lot of needs in bilateral trades and reduces the margins, and helps to keep energy trading in this sense competitive. You probably see more micro grids popping up, probably still connected to the larger grid as a whole but you see peers trading with peers and you see a lot more where the blockchain facilitates the marketplace with PV, storage and home batteries, and all of this, and trading amongst each other and instead of this centralized system that we have now. And you see that happen more and more gradually." (Interviewee 1, 2017)*

In this micro grid example, the blockchain is used to facilitate trust and privacy in the network, while tracking the order of valid transactions between nodes. As a simplified example, through the automated blockchain system, a solar array is able to autonomously sell its electricity directly to the highest bidder, whether it is a battery unit, an appliance, or an electric vehicle. Similarly, the battery unit functions as an autonomous economical actor, trading with electricity, represented by tokens in the blockchain network. Matching of the buy and sell orders initiated by the nodes can be executed through smart contract applications that react to the fluctuating spot prices of the external grid and to the internal device-to-device market of the housing society. Supportive layers such as machine learning and analytics services can be used to further optimize the automated activity within the network. (Mattila et al. 2016a)

- *The blockchain really facilitates energy system in accommodating intermittent and localized production that have a much smaller scale, and I suppose I think that's potentially in the long term, that is the largest impact that the blockchain could have on the energy sector. (Interviewee 1, 2017)*

Bilateral energy trading is an example on the establishment of local energy communities. All interview respondents elaborated such vision for the future in variable detail, while similar concepts were also identified in the secondary research material. As contributors to the management of ever-growing demand and increasingly intermittent supply of energy, local energy communities are considered as essential actors in the future energy ecosystem, whose emergence should be enabled and incentivized through legislation. This type of development trajectory proposes multiple benefits. For example, through its disintermediating properties, the blockchain is considered to enable complete end-user access to energy markets, shifting the power balance of the industry towards the end-users instead of producers and distributors. Also, when transactions are executed locally, individuals may become more aware of their energy usage. In this scenario, it can be anticipated that while the end-users start also to consume energy they have produced themselves, they also reduce their overall consumption, and shift their demand to match their supply. This may eventually translate from the household level into community level. Through awareness on the origins of energy, and the existence of local and personal communities, incentives may be created for better energy management and even energy philanthropy. This may open up novel opportunities for business model development.

5.3.2. Electric vehicle roaming

Combustion engine vehicles are a major source of CO2 and NOX emissions. This is creating significant negative externalities especially in areas with dense population. Consequently, many countries are committed to support the electrification of mobility. Currently, two relevant low-emission mobility technologies can be identified in the regime domain of our society: The electric vehicles (EV) are either Plug-In-Hybrids (PHEV) incorporating an electric motor beside a combustion engine, or Battery Electric Vehicles (BEV), completely reliant on an emissionless electric motors.

The transition to electric vehicles is a large-scale process involving many interactions between consumers and other stakeholders over decades (Kangur et al. 2017). In general, the wide scale adoption of electric vehicles is considered to be hampered by the lack of charging infrastructure, too many types of charging contracts, lack of interoperability between systems, poor transparency, and the lack of simple solution for contract-less charging (Slock.it, 2017). Indeed, significant barriers for the technological transition are facilitated by the complexity of the charging process of electric vehicles. A recent study presenting an agent based diffusion simulation on EVs shows that the increasing number of fast charging service stations causes the satisfaction with BEVs to continuously rise, resulting that by 2025 BEVs are on par with gasoline vehicles and are perceived almost as satisfactory as PHEVs (Kangur et al. 2017). This suggests that the development of the charging infrastructure is particularly important for decarbonizing mobility.

EV charging is different from fuelling a car with gasoline. Despite of fast charging technologies, the process still takes significantly longer than filling a tank with gasoline. Hence, the key in enabling an efficient EV charging infrastructure must rely on decentralization and micro-transactions that can be executed almost anywhere and anytime. In other words, the end-user must be able to flexibly and seamlessly charge the vehicle along every section of the journey, whether it be standing in the traffic lights, staying at home, or visiting a friend.

Energy companies are currently exploring the applicability of the blockchain technology as a backbone for electric vehicle charging systems. Interviewee 1 from Fortum provided an example on the *"block charge"* -project they have been working on, partnering with start-ups, and a large German utility company RWE. The objective of the project is to create a blockchain system, which seamlessly facilitates electric vehicle roaming, charging, and transactions.

Interviewee 4 proactively further elaborated the use-case. In the future, it will be increasingly important, that private housing societies and public buildings are equipped with flexible electric vehicle charging infrastructure. This essentially means that every electricity outlet should be capable of facilitating the charging process transactions. However, this scenario and requirement incorporates rather complex issues. For example, installing physical payment terminals into a large number of electricity outlets is not a viable option from both economic and technical perspectives. Also, the current supply chain structure creates problems in many instances. For example, when a housing society purchases its electricity from a utility company or a retailer, it needs to establish contracts with its internal stakeholders in order to distribute the electricity to the end-users who consume it. The easiest way is to collect the payments for the used electricity based on meter readings in a form of a maintenance charge. However, this is not a viable option when an external person arrives at the parking lot of the housing society and needs to charge his EV. Moreover, from the consumer's perspective, it is not applicable to engage in contractual relationships with a myriad of parking lot operators. Rather, a direct connection to an open marketplace where electricity can be purchased as a service would provide an optimized solution.

The blockchain is considered as an ideal technology for enabling a decentralized network, where anyone can share their private charging stations, and securely and transparently receive compensation for the usage. The key benefit of the blockchain is its capability to facilitate transactions between untrusted parties, thus creating a neutral forum for market activities, such as buy and sell orders. By utilizing smart contracts, ad-hoc relationships can be established directly and automatically between the vendor and the buyer, when pre-determined criteria are fulfilled. Importantly, trust between the actors in not needed in a sense that it is natively facilitated by the blockchain system.

In a blockchain-based EV-solution, the station owner benefits in terms of reduced liability, as there is no need to initially purchase the electricity from the retailer. Smart contracts can be programmed to automatically compensate the end-point owner according to its usage and mutually agreed terms and conditions. The end-user benefits from the freedom of choice and cost, as the contract can be made directly with a vendor offering the lowest price. In a such open market, the electricity retailer is able to deliver its offering to an increased number of end-points, thus reaching more customers. Due to the deterministic functionality of smart contracts and the blockchain itself, all parties involved benefit from automation, auditability, and transparency for example in terms of invoicing. Such open and neutral system structure would enable an establishment of a multi-sided EV charging platform, where both value creation and capture opportunities are improved due to positive network externalities. Yet, it can be argued that this scenario is not plausible if regional DSO monopolies that prevent energy roaming continue to exist.

5.4. Development of blockchain energy applications

The importance of having a clear understanding on the blockchain technology before engaging in practical implementations is essential. The technology itself incorporates a set of fundamental properties that must be matched with the business application itself. Most importantly, blockchain is a technology for shared databases utilized by multiple concurrent writers engaging in transaction and interaction in the presence of mistrust among each other, while a set of rules and validation schemes enforce trust in the system and backs up the assets also outside of the blockchain. (Greenspan, 2015b) Through extensive empirical research, Mattila et al. (2016b) validated the development requirements and criteria proposed by Greenspan (2015b) and refined them into a six-step checklist for blockchain use-cases presented in the table 13. In addition, by developing a conceptual blockchain platform for peer-to-peer energy trading, Murkin et al. (2016) identify three key requirements for enabling blockchain applications in the energy context, as presented in the table 14.

#	**Requirement**
1	A database shared by multiple parties
2	Enabling multiple concurrent writers
3	Maintaining consensus regarding the content of the database
4	Interacting modifications
5	The absence of trust
6	The undesirability of intermediation

Table 13. A checklist for blockchain use-cases (Mattila et al. 2016b)

#	**Requirement**
1	Electricity needs to be verified with the generation time and amount recorded
2	Each unit of electricity must only ever be represented by one token on the network
3	Trades must be traceable and auditable

Table 14. Key criteria for enabling P2P trading of electricity (Murkin et al. 2016)

Both of the previously described use-cases represent the two most significant themes identified in the table 12, and fulfil all the criteria for blockchain implementations as defined in tables 13 and 14. However, both use-cases could be as well established with traditional centralized database technologies. Yet, the research data suggests that the increased benefits of utilizing blockchain as a shared platform for such systems materialize in long-term, as more ecosystem sides join in for value creation and capture. Indeed, the blockchain is an ecosystem technology, reliant on a large number of participants. This theme was further elaborated by Interviewee 4, who described the BOND project initiated at VTT to facilitate the emergence of such blockchain ecosystems across multiple industries by planting the seeds of development through simultaneous pilot projects with multiple different business organizations, aiming to create synergies and network effects. This is considered as a significant technology push, as the dominant industry logic typically favours centralized and mature technologies for executing core business operations. However, incentives for developing blockchain solutions in incumbent organizations seem to arise from the fear of creative destruction and curiosity to develop and exploit novel business opportunities.

- *“We are early, but hopefully not too early so the seeds will then... it's not that it's the desert where we have thrown the seeds, so in a way the soil should be ready for the seeds now and hopefully the seeds that we get from the BOND project will start growing and then with the continuation projects they will evolve to bigger things.” (Interviewee 4, 2017)*

In the case of a wide-scale network, achieving a high transaction throughput capability is essential for the blockchain system. This could be achieved for example by implementing Microsoft’s Coco Framework into the system (Microsoft, 2017). As in the energy-domain, the nodes are typically located in physical IoT objects with limited digital storage capabilities, a backend network of full nodes hosted in data centres is most likely required. Existing solutions and proposals such as the BigchainDB (McConaghy, 2017) and IPFS (Banet, 2014) are already available for experimenting. Importantly, an ecosystem of smart contracts is needed in order to facilitate automation and interoperability across different systems. As the emergence of competing blockchains systems can be anticipated, it is essential that the blockchain ecosystem is designed to be fundamentally blockchain-agnostic, meaning that transactions can be executed across different blockchain fabrics. Therefore, as emphasized by Interviewees 3 and 4, the establishment and management of the platform boundary resources, constituting the developer tools and APIs of the blockchain ecosystem become highly important. In this context, ISO and its worldwide affiliates have initiated collaborative standardization work on the blockchain technology. The EU Horizon 2020 project also supports this development trajectory, for example by funding the SOFIE-project that aims to create a comprehensive federation framework adapter for IoT interoperability and inter-ledger transactions across blockchains.

- “That is the thing that it should be compatible... Ok it could be that the house is using Ethereum or something else and then okay, you have to convert or then there should be markets that you can sell your things and then exchange these. It won't be that you have 27 different kind of charging equipment or interfaces in your car. It should be that let's say there's a solar coin ecosystem.“ (Interviewee 4, 2017)

Blockchain is essentially a digital database with limited capabilities for interaction with entities outside the blockchain, and in the physical world. Maintaining trust, security, and transparency between parties even when transactions are based on physical commodities like electricity is essential. Correspondingly, both of the presented energy use-cases are highly dependent on physical instruments such as batteries, smart meters and charging stations. Hence, physical identification of contact between specific parties must be verified securely, while the necessity to measure electricity flow at multiple stages becomes essential. Proximity verification could be achieved for example by utilizing RFID based NFC chips to validate cryptographic signatures. Alternatively, BLE or Wi-Fi technologies can be utilized to enable longer range for near-field verification.

What comes to the validity of measurements, trust could be established in the blockchain network by implementing a proof of activity scheme for smart meters. Importantly, the applied consensus protocol should not be based on computation power like proof of work, but rather facilitate trust between the nodes by validating the presence and usage of the meters. For example, in addition to frequent network pings, both parties of a transaction could be required submit their measurements as a part of the block into the blockchain. Consequently, the blockchain can provide an efficient platform for securing the integrity of the physical meter readings, as if cryptographic keys, timestamps and transaction readings are cumulatively stored and matched in the distributed ledger, it is possible to detect malicious behaviour for example in terms of bypassing the smart meter or falsifying readings. This basically enables to eliminate the outliers in the network. For example, if a charging station consistently produces deviation compared to its transacting party, the information will spread quickly throughout the network. However, this protocol would be applicable mostly in short distance transfer of electricity due to natural energy losses in transmissions. In this sense, through its transparency the blockchain provides a reputation system, which prevents malicious behaviour. Yet, an emergence of third party certification providers and oracles in the blockchain environment can be anticipated due to business opportunities and demand in added security services.

- “Even without the blockchain, we need to also trust them (smart meters) now. But you know, if you have linked all the meters in the blockchain and then we can see the odd one out like the outliers that okay every other meter here has this reading but this one has total different reading and if you count them all together we can see that there is something missing here in the big picture.” (Interviewee 2, 2017)

Energy is a commodity with natural scarcity. The importance of constant energy access and security is highly critical. This essentially means that the capacity of the energy grid must be balanced at all times, and inputs need to be matched with outputs. Due to such security issues, a consortium blockchain system appears to be the most suitable option for the energy use-cases, at least in the early stages of technology development and adoption. The consortium model provides additional degrees of freedom in terms of network consensus and integrity, as this can be managed on multiple levels. Proof of activity scheme could be combined with user-whitelisting, and modern database consensus algorithms like Paxos or Raft. Choosing a consortium model blockchain over a centralized service provider provides multiple benefits. For example, instead of one central trusted party, the trust can be divided among many facilitators. In a such blockchain system, each consortium operator could for example represent an energy community, which can contain a myriad of actual end-points on sub-levels. Also, as the blockchain database grows cumulatively, running full nodes, and transaction validation on a community level solves many problems related to limited processing and storage capacity of individual end-points.

An extensive blockchain platform in the energy sector is dependent on the participation of the grid operators and owners. After all, physical power lines are essential for completing electricity transactions. Either the DSOs need to be integrated into the blockchain platform, or alternative power lines need to be built to connect energy communities. TSO participation in the blockchain system and electricity trading itself is not generally considered as essential, as long as information on the completed transactions are accessible by the TSO, enabling grid balancing activities on the TSO level. Another option for development would be to utilize blockchain for facilitating virtual energy communities and power plants. In this option, physical power lines between the contracting parties are not necessary, as the blockchain and its smart contract layer could securely and transparently automate end-point behaviour in terms of distribution, consumption, and abstention from energy usage. In this sense, blockchain could facilitate virtual power plants, turning demand response into a valuable commodity. For both options, proof-of-concept testing can be easily conducted locally within energy communities where end-points are in the proximity of each other. In addition to start-ups, multiple industry incumbents, such as Fortum, have already indicated interest towards such experimentation. Consequently, the development trajectory of blockchain energy ecosystems may develop either through grass-roots-level experimentation, or because of strategic R&D of industry incumbents and start-up collaboration. Either way, the research data emphasizes joint efforts with research institutes developing state-of-the-art knowledge on the blockchain technology as highly important.

6. Discussion

Based on the previously elaborated case study, this chapter discusses the development trajectory, and the implications of *the blockchain technology* in the context of *the Finnish energy sector.* The theoretical framework of the study is implemented to establish boundaries for abductive analysis on the emerging technology and its surrounding environment. Accordingly, research data is interpreted based on a content analysis coding created to reflect the components of the framework and connect the findings with the literature.

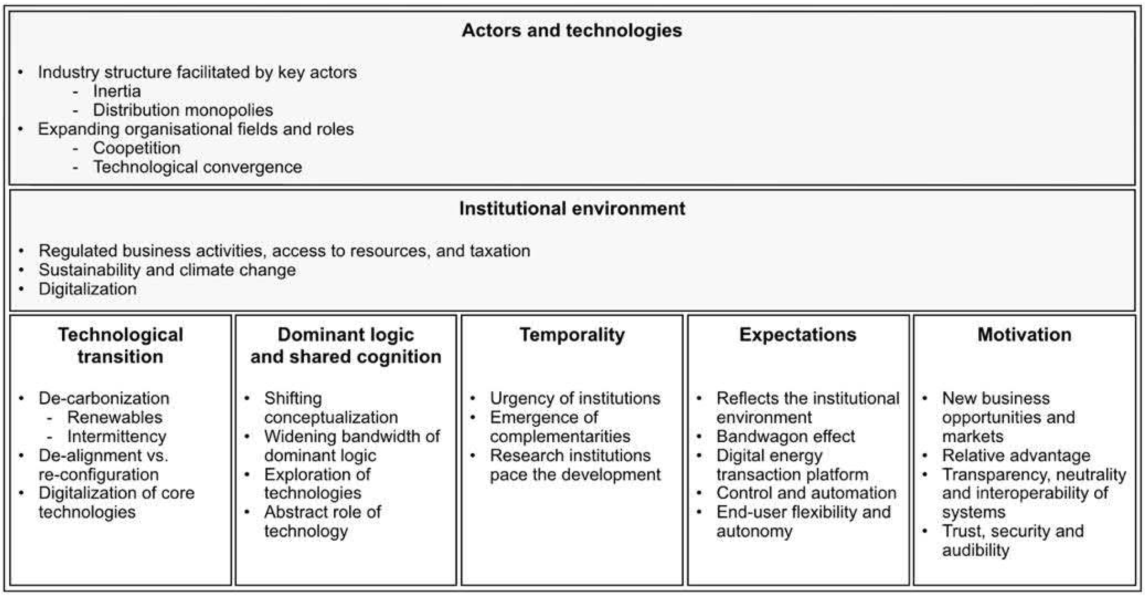

Figure 25. Revised theoretical framework canvas

The revised framework (figure 25) presents the key findings of the research data mapped onto a canvas, enabling multilateral elaboration of the research questions of this study. The following chapters provide an in-depth review per each specific component. However, because systemic transformations are complex non-linear processes (Geels, 2002; Adner & Kapoor, 2015; Ansari et al. 2016; Aarikka-Stenroos & Ritala, 2017; Dattée et al. 2017), it is important to note that the identified components are highly interconnected with each other. Thus, the canvas needs to be considered as a holistic analysis framework.

6.1. Actors and technologies

Ecosystems consist of a myriad of directly, indirectly, and even loosely interconnected actors, technologies, and institutions (Aarikka-Stenroos & Ritala, 2017). This concept describes *"the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize"* (Adner, 2017). The analysis on the Finnish energy sector revealed a set of key actors (see table 8), that incorporate centralized power and influence over the value proposition of the energy ecosystem to facilitate energy access, security, and infrastructure. The industry core consists of a natural TSO monopoly and regional DSO monopolies. In addition, the energy production is dominated by large utility companies, whereas energy retailing is focused around a few market places. From the perspective of an end-user, the energy market is arranged as a hierarchical collaboration between the producers and distributors that utilize their resources to satisfy the needs of the customer. This is an example of prototype B, as demonstrated in the figure 8 (Amit & Han, 2017). All industry activities are tightly regulated on both national and international levels. Due to these industry characteristics, the consumer side of the ecosystem has traditionally had little options available for consumption or decision making in the energy domain.

The core technologies that describe the transformation processes on how inputs are converted into outputs (Hatch, 1997, 128-130), are identified in the Finnish energy sector as production, distribution, and consumption. This abstraction is established to reflect the overall value proposition of the energy ecosystem, while the actual outcomes are achieved through a myriad of sub-technologies. Importantly, the energy sector is identified as a distributed sociotechnical system that functions through the interplay of multiple technologies (Geels & Schot, 2007). Yet, these technologies, that are fundamentally based on physical activities and infrastructure, are controlled by a rather homogeneous group of stakeholders.

Even though the energy sector in general is becoming increasingly decentralized due to the diffusion of renewable energy technologies, the Finnish context incorporates natural inertia for such development trajectory. Indeed, the geographical location of the country is not optimal for small scale energy production with PV-panels, due to the low amount of sunlight available. Consequently, in the context of the renewables, the Finnish energy sector is being focused around hydro -, and bio-energy technologies, often hosted in a large production plants. This further develops the industry centralization, establishing barriers for emerging platform ecosystem technologies.

Pressure for innovation originates from both internal and external development trajectories (Sundbo, 2002). This can be also observed in the research material. Technological development is expanding the variety of actors participating in the energy ecosystem, thus increasing complexity in the organizational fields of the energy sector. For example, the emerging commercialized home automation, electricity storage solutions, electric vehicles, and IoT are bridging the gap between the energy business and the consumer by concretizing the supply and demand of electricity. Together with research institutes, these technology developers that may originate from previously detached industries such as software development or automotive, represent an important stakeholder group in the energy sector development. While the emerging stakeholders face difficulties in establishing new innovations in the absence of support from the incumbents that stand to be disrupted, the pressure is simultaneously applied towards the incumbents themselves to engage in self-disruptive activities in order to stay competitive (Ansari, 2016). This development trajectory stimulates coopetition among the ecosystem actors, but also presents a chicken-and-egg problem for technology adoption.

- *“For sure the energy companies they need to be involved there but then there are regulators, that is another other big thing that that is needed. And then it's the users who should be then adopting the thing. But there is a big chicken-and-egg problem that there should be some services that you are utilizing.” (Interviewee 4, 2017)*

The blockchain technology represents a paradigm shift in the domain of the existing actors and technologies of the Finnish energy sector. Indeed, the blockchain is fundamentally a technology platform for establishing decentralized networks that facilitate P2P transactions in a digital environment (Christidis & Devetsikiotis, 2016;

Tschorsch & Schauermann, 2016; Weber et al. 2016; Zheng et al. 2017), whereas the Finnish energy sector represents a collection of centralized organizational fields and physical infrastructure. Hence, the blockchain presents an introduction to a fundamentally different system architectures. The centralized databases and information systems currently used in the energy sector are established as substitutes for the blockchain technology. After all, digital transactions can as well be managed through privately owned services (Yli-Huumo et al. 2016).

Misalignment of the emerging technology and its surrounding socio-technical regimes can be identified, establishing challenges for wide-scale adoption. Yet, the socio-technical regimes are not static, but rather evolve through interaction with emerging technologies and landscape environment changes (Geels, 2002). This indicates that despite of initial misalignment, an emerging technology may be targeted towards the beachheads of the regime domain. For example, permissioned blockchain system alternatives, controlled by single or multiple entities offer familiarity for the regime domain, by applying the principles of the blockchain technology into centralized networks, creating controlled environments for taking the advantage of the benefits of the technology platform. In addition, the value proposition of the blockchain technology in efficient and secure management of transactions in complex networks of distrustful entities (Beck et al. 2016), may be anticipated to benefit from the increasing structural complexity and coopetition of the energy sector, correlating positively with the adoption of the innovation.

The blockchain technology enables a complete bypass of third party actors in transactional relationships, thus creating advantages in cost and efficiency (Christidis & Devetsikiotis, 2016). Consequently, any organization that provides trust or intermediary services between parties is vulnerable to blockchain substitution. Whereas the existing web 2.0 framework facilitates the internet of information, the blockchain is considered to unlock the internet of value (Zheng et al. 2017). Hence, the blockchain represents a generative technology that provides an unbounded range of value propositions across multiple industries. This suggests for an impending technological convergence, referring to a process where two or more different industrial sectors become sharing a common knowledge and technological base (Athreye & Keeble, 2000). Such events redefine the boundaries of existing industries while also creating new products or entire industries (Schnaars et al. 2008). As a result, re-arrangement of the energy ecosystem actors and their roles may be anticipated. For example, as previously elaborated in the case study description, the blockchain may be used for facilitating P2P electricity trading in local environments, or even in wide-scale vehicle charging networks. Such scenario changes the positioning of the central actors of the energy sector, such as the TSO and DSOs from mutual collaborators (figure 8, prototype B), into transaction enablers (figure 8, prototype C) that operate by matching needs and resources through sorting and prospecting bundles of products and services (Amit & Han, 2017). Indeed, as the blockchain database can only be appended, size will eventually become a challenge (Christidis & Devetsikiotis, 2016), restricting the possibilities of small scale users to participate in the network. This could be seen rather as an opportunity, than as a problem. Perhaps hosting full nodes (Tschorsch & Schauermann, 2016) in the electrical network emerges as a novel business opportunity for the DSOs in the future. This notion represents a radical paradigm shift in energy business, transforming the physical network providers into digital service providers and data organizations.

6.2. Institutional environment

Technologies exist embedded in the institutional environments that shape them (Garud et al. 2002). These environments consist of the underlying regulative, normative, and cognitive contexts (Vargo et al. 2015) of the organizational fields embedded in the ecosystem structure. Moreover, this definition includes the relevant regulators, policymakers, and interest groups (Ansari et al. 2016; Granqvist & Gustafsson, 2016). Together the institutions govern the production, distribution and consumption associated with technologies (Garud et al. 2002). The previously presented ecosystem visualization (figure 22) may be used as an overview on the institutions of the Finnish energy sector.

The research material presents evidence on the importance of institutions in the development of the Finnish energy sector. Indeed, the industry is highly institutionalized due to the importance of electricity as a commodity that facilitates the functionality of the society. The regulatory framework of the energy sector which is established on multiple levels, including the EU and national policy making, impacts not only the physical transfer of electricity, but also the information and data related to all activities. Such complexity in regulation presents barriers for innovation activities, but also provides an effective vehicle for implementing new technologies. For example, multiple interviewees referred to the adoption of the AMR meters in Finland as a positive implication of regulation. Further regulatory actions to open up the access to electricity markets, for example by dismantling regional DSO monopolies, could significantly increase the rate of innovation in the energy sector.

Electricity taxation and access to energy resources were identified as prevailing themes in the research material. These themes are highlighted as institutions due to their dependence on the regulatory framework. More particularly, the current electricity taxation model de-incentivizes market -, and demand response participation, whereas the access to energy resources is highly restricted due to the existence of distribution monopolies. This presents a challenge for implementing any kind of transactive solutions in the energy sector, including the previously elaborated blockchain use-cases. Fortunately, the regulators also identify these hindrances. Due to the importance of mitigating the climate change, and the institutional pressure from the EU, enabling innovation activities has become a paramount objective for policy makers. Sustainability has become an institution itself, that mediates the cognition, values, and decision making on multiple level of the society. This is an indication of institutional work on reconfiguring the belief systems (Lawrence & Suddaby, 2006, 221) of the ecosystem actors. Indeed, evidence on political work attempting to reconstruct the rules of the institutional environment is identified.

- *"If you take a look at for example the energy storage. There's been lots of lobbying and complaints about certain laws like the double taxation law on energy and now the EU and on a national level the regulators are looking to change for that. And that was in response to interest in the market." (Interviewee 1, 2017)*

- *“The EU Commission’s Clean Energy Package suggests for enabling local energy communities to establish and run their own distribution networks across properties.” (Interviewee 5, 2017)*

Along with the expanding organizational fields and converging technologies across industries, digitalization is being established as a normative institution. Indeed, availability of information, and 24/7 digital connectivity is rapidly becoming a norm in the society. Hence, reliability of ICT systems has become paramount for modern organizations. This has also created implications in how modern businesses need to consider their own operations. Yet, the energy sector operates fundamentally within its physical infrastructure incorporating long investment cycles and systemic interdependence. Consequently, even though the evidence on the disruptive implications of digital technologies across various industries is irrefutable and inevitable (Korhonen, 2016; Cohen et al. 2017), the energy sector may be considered to incorporate natural inertia against the digital disruption.

Misalignment can be identified also between the blockchain technology and the institutional environment of the Finnish energy sector. This finding mainly arises from the comparison of the restrictive regulatory environment of the energy sector with the open and democratic ideology behind the development of the blockchain technology. Hence, the institutional environment presents a significant adaptation chain risk (Adner, 2012) for the blockchain technology. Before blockchain applications may become widely adopted, regulation and standardization is likely required (Christidis & Devetsikiotis, 2016; Weber et al. 2016). For example, supportive regulatory frameworks are needed to enable and enforce the emerging concepts such as smart contracts as legally binding agreements (Wall, 2016). Yet, the industry spanning development of the blockchain technology appears to have triggered institutional work especially in terms of advocacy, defining, theorizing, and educating, that develops implications also in the energy sector. Indeed, a compelling vision typically reduces uncertainty, facilitates coordination, and enables the establishment of a future ecosystem vision as an impending reality, prompting stakeholders to join the early movement (Ozcan & Eisenhardt, 2009).

- *“This year there has been already several events and a lot of discussion in the EU commission about the blockchains.” (Interviewee 4, 2017)*

- *“A good example is, I went to early adopters’ conference in London which was held by Ponton and it was all the major energy traders in Europe with that. We were all discussing together how we would like a platform and marketplace to look like on the blockchain, and what would the improvements be.” (Interviewee 1, 2017)*

- *“Yes, there is standardisation plans and VTT is one part of it with other participants also in Finland and of course in many countries that are interested about this.” (Interviewee 2, 2017)*

Institutional work is a central process in technology development (Lawrence & Suddaby, 2006, 215). However, profound understanding on the fundamental properties of the technology in focus, and its surrounding environment is essential before engaging in practical implementations. This also refers to finding suitable anchor points for the new technology within the surrounding institutional environment. Identifying the applicability and benefits of the technology, and connecting them with the familiar societal themes and issues of the institutional environment, may provide avenues for creating supportive institutions. In other words, institutional work needs to be considered as a strategy process, that combines creative activities with carefully controlled and targeted disruption, and defence from the encountered attacks and undermining of the dominant regime.

6.3. Technological transition

Technological transitions, that refer to major technological changes in the way societal functions are fulfilled, develop under the pressure of the landscape environment, dominant socio-technical regimes, and emerging technologies (Geels, 2002). The research data indicates the existence of an ongoing technological transition in the Finnish energy sector, entailing a transformation from traditional company based ecosystem towards a systemic setup, where different stakeholders operate as value-co-creating parties. Hence, a need for a neutral ground between organizations emerges. More particularly, because technologies exist embedded in institutional domains (Garud, et al. 2002), this transition reflects the dominant institutional emphasis on digitalization, sustainability, and mitigation of the climate change. In general, digitalization complements the on-going de-carbonization process that develops through substitution of fossil fuels with renewable energy technologies. Such transition trajectory is simultaneously increasing the overall intermittency of electricity supply and demand. However, due to the lack of sufficient technologies for solving the issue of intermittent energy in wide scale, de-alignment of the regime domain becomes plausible. This refers to a scenario in which the regime domain is being "hollowed out" while no stable niche-innovations capable of "filling the gap" are available (Geels & Schot, 2007).

The importance of the regulatory framework in the development of the Finnish energy sector can be identified clearly in the research data. Indeed, in addition to companies seeking for new business opportunities and revenue growth, the technological transition of the Finnish energy sector is mainly driven by a technology push from the institutional field, that stimulates the industry development through emission regulation and incentives for clean technologies. Concrete technologies that integrate the end-user into the energy ecosystem are highly needed.

- *"…I meant the industry professionals. The consumers are probably mostly out from this development, and that's what we are here thinking on how to communicate these changes." (Interviewee 5, 2017)*

The de-carbonization of the energy ecosystem is considered as an iterative process facilitated by innovation activities and institutional work, that expands the organizational fields of the energy sector by connecting new actors into the system structure. This develops two-folded implications in the core technologies of the energy sector. Institutional work conducted in the regime domain stimulates the development of the existing core technologies, whereas the emergence of new technologies re-arranges, and enables novel transformation processes, thus re-configuring the socio-technical regimes and the institutional environment (Geels, 2002; Hatch, 1997, 130; Weick, 1990).

Even though the core technologies of the Finnish energy sector have been traditionally based on physical and regulated activities, a prevalent technological transition can be identified especially in the domain of digitalization. More specifically, the underlying sub-processes of the core technologies are becoming increasingly digitalized and democratized. This reflects a paradigm shift in the technologies of the energy sector, causing a significant and disruptive impact on the roles of the ecosystem actors. On the detailed organizational levels, the developing technological transition is transforming every day work and the requirements for continuous learning and adaption. It has been widely acknowledged that traditional industries such as the energy sector need to transition from physical hardware towards an increasingly customer-centric service offerings.

The developing digital technologies across industries complement each other by conceptualizing the symbiosis between the physical domain of electricity and the digital realm. For example, the Datahub project by Fingrid that aims to consolidate all relevant industry information into a single database, is considered as a significant leap towards a digital energy system. This initially disrupts the operations of the ecosystem actors that are accustomed in hosting their own private data silos. However, the value proposition might materialize in the future even though the disruptive effects are felt immediately (Ansari et al. 2016). As the digitalization of the energy industry progresses, a new status quo of organizational activities becomes increasingly stable and institutionalized, reframing disruption into creation. This may be considered to initialize the regime domain for digesting radical innovations such as the blockchain. However, many contemporary challenges remain, for example in how to connect data of digital transactions with real world physical transactions of electricity, while data can be easily copied, modified and falsified. Hence, the issue of trust emerges as a central factor in the technological transition.

- *"The difficult challenge is once you've completed the digital transaction, how do you ensure that the correct amount of electricity is going from the correct party A to correct party B, in the real world." (Interviewee 1, 2017)*

The value proposition of the blockchain technology presents solutions to many of the hindrances of the ongoing technological transition. With its core capabilities, the blockchain enables the establishment of trust, integration, and automation across systems by leveraging micro-transactions and smart contracts (Christidis & Devetsikiotis, 2016). Such technology is needed for enabling efficient management of intermittent energy production and consumption. Pilot projects and concepts such as the *"block charge"* by Fortum, and the BOND-project by VTT incorporate important roles in the industry development trajectory, by conceptualizing the applicability of the emerging technology in solving specific problems and creating novel solutions. Such adoptions are often driven by economic considerations, leaving most regime rules unchanged (Geels & Schot, 2007). The gradual re-configuration of the regime domain may prompt further systemic changes and technological convergence. For example, the blockchain could be later utilized in the Datahub to implement capabilities for distributing the validation process of transactions among the network participants, thus positively correlating with trust associated with the system, and the entire electricity markets.

- *"One of the obstacles that we see within the blockchain technology is that currently the blockchain applications are basically applications for one type of a thing. There are no really sort of a multi-purpose blockchain applications yet." (Interviewee 3, 2017)*

In distributed sociotechnical systems such as the energy sector, transitions are not caused by the breakthrough of a single technology, but rather by sequences of multiple component-innovations (Geels & Schot, 2007). Indeed, the blockchain represents a generative infrastructure technology for digital trust, automation and integration, that enables creation of increasingly sophisticated and easy-to-use products and services. In wide-scale, such innovations that consist of multiple components, provide the vehicles for conceptualizing the energy sector transformation to the end-users. Hence, the blockchain technology indicates re-configurative implications in the technological transition of the Finnish energy sector. This emphasizes the importance of rather considering the blockchain as an ecosystem, than as an individual technology. Explicit formulation of questions such as “who else needs to innovate to make my innovation successful” or “who else needs to buy in to enable the adoption of my innovation” (Adner, 2012; Adner & Kapoor, 2015), becomes highly important for technology and business developers.

6.4. Dominant logic and shared cognition

During its course of history, the energy industry has witnessed multiple technological transitions, from steam engines to coal plants and petroleum, all the way into harnessing the power of nuclear energy and renewable energy sources. Over time, activities develop into a dominant logic that provides frameworks for sensemaking processes (Prahalad & Bettis, 1986; Bettis & Prahalad, 1995). This creates a lens for interpreting the surrounding environments, thus mediating the activities and strategy formulation (von Krogh et al. 2000). The research data suggests that the Finnish energy sector incorporates a legacy in dominant logic reflecting one-way supply chains and a passive role of the end-user. Access to energy markets has traditionally been the privilege of a limited group of business organizations. However, as also discussed in the previous sections, due to the emergence of digital technologies and commercialized energy solutions, the power balance is shifting towards a dialogue between the end-users and the institutional actors. Indeed, the emergence of digital technologies has significantly reduced information asymmetries and friction between market actors, by enhancing transparency and efficiency at which resources are exchanged, combined, and integrated, thus significantly expanding the range of resources organizations can access, and the needs they can address (Amit & Han, 2017). Along the trajectory of the technological convergence and expansion of the organizational fields, a shared consensus, describing the collective behaviour in organisations how they interpret their environment and act within it (Johnson, 2011), is developing on the importance of the end-user role in countering the climate change.

- *“…If you go back to very fundamentals, its the climate change… a need to reduce emissions in the energy sector.” (Interviewee 1, 2017)*

The dominant logic of the Finnish energy sector reflects on its actors, technologies, the institutional environment. The ongoing technological transition re-configures both the internal, and external conceptualization of the ecosystem actors, creating implications in strategic action and performance (von Krogh et al. 2000). More specifically, the internal conceptualization on people, culture, and product and brand is becoming increasingly active and important. Pressure for such change originates from the expansion of the organizational fields and technological convergence. As new actors enter the markets and technologies become increasingly accessible, competitive advantage must be secured by focusing on valuable, rare, imperfectly imitable, and non-substitutable resources (Barney, 1991), that are increasingly often created as value co-creation within the ecosystem. Importantly, institutional work on the climate change, sustainability, and digitalization, resonating from multiple domains of the energy ecosystem, is placing people into the centre of focus. Such ubiquitous societal themes provide effective catalysts for re-configuring and establishing shared cognition on the external conceptualization on competitors, consumers and customers, and technology by emphasizing the importance of collective activities and cooperation in achieving objectives. As consequence, exploration of technologies and platform business models are becoming rooted into the dominant logic of the energy ecosystem.

- *“You see a lot of that happening and then you also see a larger industry players whether it's IBM, whether it's utilities like Fortum, we are always looking to collaborate with start-ups, like for example Slock.it.” (Interviewee 1, 2017)*

- *“I think even the smallest companies have accepted the idea of the Datahub.” (Interviewee 5, 2017)*

Along the technological transition of the Finnish energy sector, developing the bandwidth of dominant logic in organizations becomes increasingly important. Indeed, restrictions for the range of imaginable options in business results in incapability to perform in changing environments (Bergman et al. 2017). This may be challenging especially in the context of radical and generative technologies that present an unbounded range of potential applications, thus providing little guidance for sensemaking (Dattée et al. 2017). The blockchain provides an example in this context, as understanding the technology in business use is generally considered as rather challenging.

- *"It's extremely rare to find someone or almost unheard of to find someone who has a lot of knowledge of blockchain and the energy sector… It is feeling around in the dark, and very much of elevator thinking. No one really knows what is the best course of to take with the blockchain." (Interviewee 1, 2017)*

- *"It's the biggest challenge because there's not really many people who can see the big picture. Even me, I know how the technology works but I don't have any experience about the business area. So, of course in research projects we have some business experts and blockchain experts and security experts and energy experts. We try to combine our knowledge and vision, but it's not always so easy thing to do." (Interviewee 2, 2017)*

These findings emphasize the importance of trailblazers, such as the BOND project, in developing blockchain applications and the energy sector transformation. Indeed, studies show that organizations tend to adopt the behaviour of other successful actors (Bogner & Barr, 2000). Yet, imitating others rarely provides optimal solutions to complex and unique business objectives. Another challenge is that businesses often tend to consider innovation from an incremental perspective, thus further restricting cognition and sensemaking. However, successful pilot projects may provide cognitive anchors for sensemaking on emerging technologies, thus widening the range of imaginable options.

- *"Many of the Finnish companies have been outsourcing their capabilities when it comes to digitalization. For me that is one of the biggest obstacles why companies are not sort of moving rapidly when it comes to these type of things as blockchain or platform economy because they don't have the thinking in-house." (Interviewee 3, 2017)*

Despite of the above discussed ambiguities, the blockchain technology has recently gathered a large amount of interest in the energy sector. The industry actors are eager to learn more about this emerging innovation, and how it could be applied in their daily businesses. Overall, the shared cognition on the blockchain appears to be rather positive and enthusiastic. For example, over 110 participants from 58 companies joined a recent blockchain seminar hosted by the BOND-project in Finland, which is considered as a relative large number in the context of a technology in such an early stage of development and conceptualization. When asked from the crowd in the seminar, only a handful of people had actually deployed anything blockchain related into a production environment.

- *“Collaboration, consortiums and large conferences are being held, and I think it's very much like that at the moment. It’s that we're all in this together, let's find out what blockchain can do for the energy sector.” (Interviewee 1, 2017)*

Convergence of cognition on future development may develop into triggering events for ecosystem emergence (Almpanopoulou et al. 2017). In this context, events and conferences on the blockchain technology incorporate a significant role in establishing the innovation within its surrounding environments. As a result, the industry actors have already successfully identified multiple use-cases for adopting the innovation. However, as previously discussed, the blockchain itself represents a generative technology which is highly dependent on components that in unison materialize the value proposition of the innovation. Hence, the blockchain technology is considered as a black box that in itself does not provide much of an appeal. This finding describes a neutral impact of the technology in cognitive processes, but rather emphasizes the importance of the actual outcomes of technology adoption. For this reason, emphasis on complementarities, technology simplification, and design of intuitive user-interfaces and flows is highly important for supporting sensemaking processes.

6.5. Temporality

Technology development is orchestrated through the timing and sequence of activities. While the pressure to innovate originates from both endogenous and exogenous factors (Sundbo, 2002), the surrounding socio-technical regime domain in its current state may not be compatible with the proposed changes (Geels, 2002). This emphasizes the importance of timing in technology development.

The energy sector is facing significant pressure for development. The climate change is considered as one of the root causes for establishing urgency for change. In the context of the energy sector, such urgency is supported by both EU and domestic policies in Finland, that define objectives and deadlines that have been even criticized as unrealistic in terms of possibilities for execution. For example, Pekka Lundmark, the CEO of Fortum stated during a keynote in 2017, that at this time, we do not have any realistic technological means for achieving the objectives of the Paris Agreement. Such explicit trajectory formulation further entrains innovation activities. This also entails a perception on irreversibility, as the only way to solve the impending issues is to engage in radical actions. Linking particular pressing interests and priorities with certain solutions, provides a baseline for an ideology of change that seeks to engage people in action (Granqvist & Gustafsson, 2016). In this context, the blockchain technology implementations are beginning to emerge in the energy sector during favourable times. The endogenous urgency may in fact present an important driver and motivation for use-case development activities, especially in the incumbent organizations. This finding suggests that urgency promoted by the institutional environment and expanding periphery of actors and technologies stimulates incumbent organizations to actively engage in self-disruptive activities.

- *“I think the trend that is really interesting in that sense that gradually it's becoming the right time to actually try out this kind of new solutions.” (Interviewee 1, 2017)*

- *“Everything will we re-arranged in the energy sector during the next 10 to 15 years.” (Interviewee 5, 2017)*

In the early stages of technology development, the blockchain implementations are being pushed towards the early adopters identified in incumbent organizations. The research data is unambiguous in identifying the lead role of research institutes in the innovation development. However, as also discussed in the context of sensemaking, a major challenge remains in combining the business knowledge of the businesses with the technical knowledge of the researchers. It appears that the developing blockchain hype has also caused negative externalities in a form of incompatibilities between the application purposes and the technology, thus also negatively impacting the development of cognition on the emerging technology. This may be considered a characteristic for a technology in its early stages of development.

- *“Now it's likely that we (research institutes) call to ask them, hey do you have some problems that we could solve with blockchains? Then we do some research if it makes any sense to use blockchains. In most of the cases, it's like people think that okay I have this problem and I want to use blockchains to solve it. But in many cases, they want to use it in wrong problems.” (Interviewee 2, 2017)*

The pace of the blockchain development is mostly determined by projects with specified milestones and deadlines. The BOND project by VTT is a good example on such holistic attempts to stimulate blockchain development across multiple industries. Despite of good progress and successful enactment of momentum, at this stage, the project is only expected to plant the seeds of development into the business organizations, whereas the typical expectations for reaching technological maturity on the blockchain solutions are estimated between 5-15 years.

- *“...no big implementations yet, but there is planning and the plans are then there and the companies have involved and taking it seriously. So, it seems that yes, it is now in much better shape then let's say one year ago.” (Interviewee 4, 2017)*

In addition to the blockchain technology, the energy sector is witnessing an emergence of a myriad of novel complementary technologies, while being increasingly exposed to other industries through digital channels. For example, in his Reboot Finland Energy keynote, Pekka Sivonen from TEKES emphasized that it has become essential to start developing ecosystems that leverage such technological synergies and industry-spanning business models. Similarities are identifiable in the interview material, indicating an existence of a temporal opening for introducing blockchain applications in the energy sector.

- "The customer requirements that have typically come through one sector are now coming through multiple, so there will be a different type of business models implemented that that go across different industries. The big thing that that what will come out in the future is the ubiquitous network of systems. So basically, it will be all about interoperability. The blockchain technology is enabling us to think the interoperability of companies and interoperability of industries in a new way." (Interviewee 3, 2017)

More specifically, the interviewed experts identified IoT, battery technologies, and ICT connections such as the 5G as one of the most important complementarities required successful blockchain implementations in the energy sector. As of now, IoT platforms are considered as emerging technologies that have not been largely adopted in mainstream consumer markets. Battery technologies are about to break through in small scale usage, but still suffer from inabilities to accommodate intermittency through long periods. 5G on the other hand has not been released to commercial usage. In addition, other blockchain applications are identified as important complementarities, indicating a need for developing the boundary resources of the technology, before a large-scale adoption becomes plausible. In congruence with the findings of Adner & Kapoor (2015) on systemic development, it may be argued that the emergence of a blockchain ecosystem will not happen, before innovation issues related to the ecosystem complementarities have been resolved.

6.6. Expectations

Organizations construct and decode their environments through expectations and typifications, that set boundaries for incoming signals, and connect novel occurrences with familiarities (Patriotta & Gruber, 2015). In the context of the Finnish energy sector, the expectations appear to reflect the institutional environment. Modern organizations are expected to strive for sustainability, and take responsibility in mitigating the environmental impact of their activities. Such expectations have far reaching implications. For example, organizations are expected to take responsibility not only of their own actions, but also of the actions of their affiliates and partners. This establishes significant constraints for partnerships due to the importance of trust and auditability. In addition to the environmental perspective, organizations are expected to be agile and able in innovation activities. Such expectations establish urgency for experimentation with new technologies.

By introducing two use-case descriptions on the expected functionalities of a blockchain-based energy system, this study identifies the potential of the emerging innovation in enabling automated micro-payments, ad-hoc contractual relationships, and peer-to-peer energy transactions. This development trajectory is expected to shift the market power towards the end-users, as the blockchain facilitates open access points to the energy markets in all sides of the energy ecosystem. However, electricity distribution on a national level is not considered to initially become under high disruptive pressure, as the developing peer-to-peer networks are expected to integrate with the DSO level. Consequently, the diffusion of the blockchain technology is expected to cause significant disruption in the operations of the DSO's and Market Operators, as they can be even completely bypassed in peer-to-peer networks. Interestingly, such expectations are formulated rather explicitly in the contemporary discourse, entailing drivers for a change (Patriotta & Gruber, 2015). This may provide an explanatory factor for the active participation of the incumbent organizations in blockchain technology development.

- *"Anybody who's has a central role in the energy system is under threat by blockchain… What they realized is they have to adopt it because they think it's going to happen anyway and they want to completely revolutionize their business models in order to still have a part to play in this new energy system." (Interviewee 1, 2017)*

- *"It's hardly disruptive for the TSO… It's more likely an issue for the DSOs. I would think so…" (Interviewee 5, 2017)*

The expected implications of the blockchain technology in the energy sector appear in congruence with the main development trends of the energy sector, such as de-carbonization and digitalization. Other complementary trends such as the rise of sharing economy can also be identified. In other words, blockchain applications are expected to become available in the niches that are expected to gain momentum in the upcoming years. This finding provides an example on targeting emerging technologies towards the identified beachheads of the surrounding institutional environment and socio-technical regime, thus enabling the initialization of re-configurative processes. For example, the research data presents anticipation on an emergence of localized energy communities, and market deregulation especially on the DSO level, creating opportunities for new digital business models leveraging blockchain-based technologies. However, such digital energy service environment could be as well implemented with centralized database technologies (Yli-Huumo et al. 2016). In fact, even though the research data presents high expectations for the transformative effect of the blockchain technology on the energy sector, the first stages of industry digitalization and systems integrations are considered to develop most likely as centralized solutions, such as the Datahub.

The emerging blockchain technology suggests a radical value proposition, by arranging transactions as P2P relationships, thus bypassing all intermediaries (Dorri et al. 2016). This is expected to present implications in all of the core technologies of the energy ecosystem, most prominently in distribution and consumption (see table 12). However, because electricity is a commodity that needs to be transferred physically, the closed distribution markets establish a barrier for implementing blockchain based solutions in the energy sector. The DSOs are currently considered to have little incentive in letting go of their monopoly positions or opening up their networks for shared usage. Indeed, the hype-cycle analysis on the blockchain technology suggests for highly inflated expectations (Jun, 2012; Gartner, 2017b). In order to redeem its value proposition, the blockchain technology needs to overcome the institutional barriers for diffusion, as previously discussed. Yet, the cumulating bandwagon effect may be considered as positive development, as the emerging cooperative ventures and development activities build momentum for the establishment of shared cognition on the emerging technology and its applicability throughout the ecosystem. Such cognitive convergence may develop into triggering events for ecosystem emergence (Almpanopoulou et al. 2017).

6.7. Motivation

Technology alone does not provide any value and is no use. Only in association with human agency and social structures and organisations does technology fulfil functions. (Geels, 2002) Hence, technology itself is not the goal for organizations or individuals (Vishwanath, 2009). The motivation to adopt technologies rather stems from the context of the emerging technology and the status quo of its surrounding environments. For example, an emerging technology may be superior to the existing substitutes in terms of relative advantage, efficiency, or compatibility (Bakar & Ahmed, 2015). Indeed, technology adoption is often driven by economic considerations (Geels & Schot, 2007). Yet, motivation may also arise other intrinsic or extrinsic sources, such as social-driven, or professional motivations (Battistella & Nonino, 2012). Consequently, motivation incorporates a significant correlation with sensemaking processes.

The economic motivation for organizations often reflects on revenue growth. Due to the technology-enabled expansion of the range of accessible resources and needs that may be addressed (Amit & Han, 2017), new markets are becoming available in the energy sector. The research data presents a consensus on the importance of developing the energy system towards an interactive network where all ecosystem sides are able to participate in market activities. For example, the market actors are indicating high interest in harnessing demand response as a valuable commodity through digital technologies. Accessing such novel market areas are increasingly often dependent on a myriad of value co-creators (Adner & Kapoor, 2010; Amit & Han, 2017), thus emphasizing the importance of developing full transparency and integration of business processes across the ecosystem. For example, validating real-life occurrences within a digital environment by utilizing traditional technologies and information system silos is somewhat problematic, and may require participation of multiple stakeholders in a single transaction. In other words, the motivation for transparency emerges from factors such as cost reduction, and new value creation opportunities. This effectively describes the extrinsic motivation of the energy ecosystem actors for engaging in coopetitive relationships (Battistella & Nonino, 2012). Overall, continuous streamlining and integration of business workflows is the antecedent for developing and maintaining competitive advantage in the modern business environment.

The value proposition of the blockchain technology constitutes of enabling secure, automated, and neutral system structures for a large number of network participants. Neutrality is considered as essential, as it motivates ecosystem sides to join the network, by eliminating asymmetrical power relations and influence that typically hinder the adoption of centralized platform solutions (Mattila et al. 2016a). In addition to individuals and organizations, the participants of modern business networks may include a myriad of IoT devices. As the emerging smart electricity solutions and IoT networks require secure and auditable data architectures for facilitating multiple parties that may exist in competing or distrustful positions in relation to each other, the blockchain is considered as an enabling technology. Cryptography utilized in the core of the blockchain provides a secure environment, whereas smart contracts built on this core enable automated real-time control of device-to-device transactions, reducing the resources required to arrange market activities (Christidis & Devetsikiotis, 2016; Tschorsch & Schauermann, 2016). This further motivates the ecosystem actors especially in terms of potential cost savings and resource allocation to develop competitive advantage. Importantly, efficient resource allocation and management enables the utilization of advanced cognitive technologies such as artificial intelligence (AI) that may be further utilized in business process optimization.

- *"If any sort of a smart agent can start communicating and making make-or-buy decisions in the future within the network, then basically the information about those transactions or keys to those transactions needs to be stored in a place where you can actually go and audit all those transactions. So, I think that the blockchain enables us to create that type of an architecture where you can basically register different type of the transactions and then everybody can go back there and check that okay this is really what happened." (Interviewee 3, 2017)*

Because of the low price of electricity in Finland, making margin in the energy business has become increasingly difficult. Hence, exploration of new business opportunities, has become highly important for industry actors. In this context, experimentation on radical innovations may provide increased competitive advantage, but also constitute higher risks. Whereas such innovations are often high in complexity, and low in terms of compatibility, trialability, and observability, organizations may be reluctant for investing in such R&D projects. The case study on the blockchain technology presents a solution to this dilemma through collaborative use-case development projects between research institutes, start-ups, and incumbent. Importantly, motivation for experimentation may be improved by isolating the use-cases from the daily operations of the business organizations. Moreover, in addition to opportunities, an important source of motivation for engaging in blockchain development projects appears to stem from a fear of an industry disruption. This finding emphasizes the importance of explicit technology formulation in terms of engaging ecosystem participants in exploratory activities.

Even though the end-users are becoming increasingly aware on their importance and possibilities to actively participate in the energy system, external incentives for such activities are low mainly due to technological complexity, taxation issues, and a lack of an open market place. This negatively impacts extrinsic motivation. However, in the context of this study, the motivation for technology adoption for the end-user is identified to stem from not only potential cost savings, but also from intrinsic factors such as satisfaction on environmentally friendly development, ease of usage, freedom of choice, or learning new technologies. This for example creates an opportunity for technology developers to introduce products and services that gamify the energy market participation by leveraging both intrinsic and extrinsic motivation in combination with blockchain-enabled applications.

The blockchain technology develops implications in the energy sector through motivations, by introducing novel value propositions that emphasize relative advantages to existing solutions. Motivation for technology experimentation appears to be higher for the actors of the ecosystem that stand to be disrupted, whereas organizations in secured positions, such as the national TSO or the government, do not seem to indicate high urgency in adopting this technology development trajectory. Reflecting on existing literature, this is an interesting finding that confirms the existence of organizational motivations to self-disrupt their own operations.

However, the concept of the blockchain technology is rather difficult to understand, creating limitations for practical implementations. In the absence of commercialized products and services, the technology itself does not impact the development of motivation past the early adopters.

7. Conclusions

This study has presented an in-depth review on how industry transformations come about. More specifically, technological transitions, referring to major technological changes in the way societal functions are fulfilled (Geels, 2002), were explored in a form of a case study on the implications of the blockchain technology in the development of the Finnish energy sector. Based on the contemporary literature on technology, innovation, business ecosystems, and managerial cognition, a theoretical framework was developed to provide boundaries for the analysis. Overall, the results present insight in the processes and mechanisms through which emerging technologies re-configure their surrounding environments.

7.1. Theoretical implications

The theoretical implications of this study indicate that emerging technologies incorporate value propositions, that stimulate motivation and expectations across networks of interconnected actors, technologies, and institutions. This challenges the dominant socio-technical regimes and triggers institutional work within the surrounding environment. Depending on the temporal and structural alignment of the emerging technology and the surrounding socio-technical regime, re-configuration processes may initiate in the dominant logic and the existing technological transition of the ecosystem structure. The emerging technologies rather cause re-configurative implications in systemic transition trajectories, than specific and sudden shocks. Thus, the high-level implications of emerging technologies in systemic development trajectories consist of stimulating and re-configuring the contemporary technological transition pathways by initiating and empowering creative institutional work that seeks to re-arrange the roles of the ecosystem actors, and how inputs are converted into outputs.

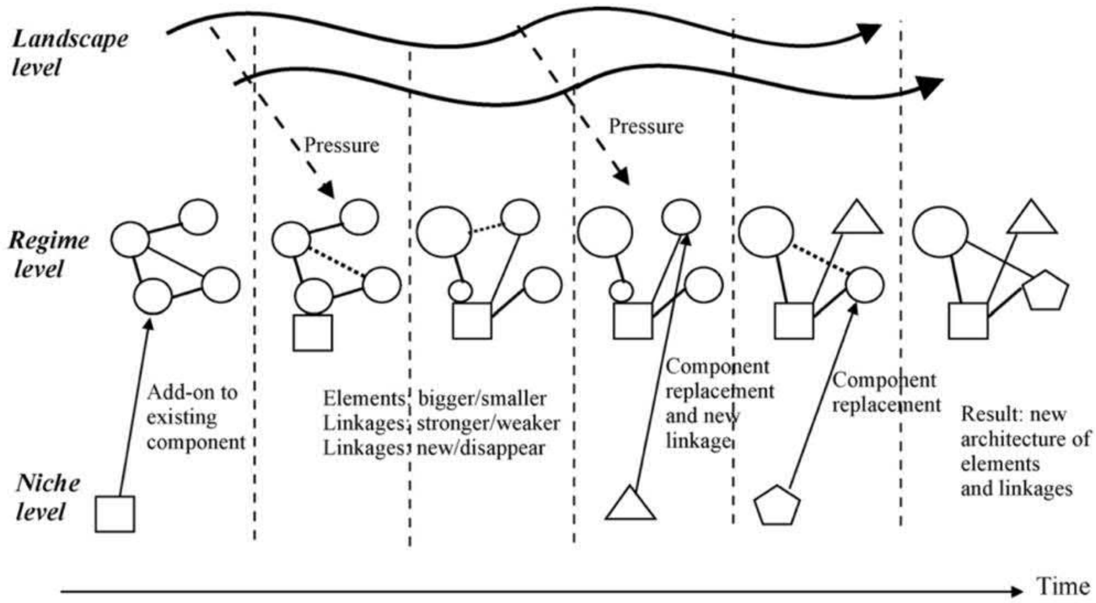

Figure 26. Re-configuration pathway (Geels & Schot, 2007)

The findings of this study correlate with the re-configuration pathway archetype for technological transitions, originally presented by Geels and Schot (2007), and also support the findings of Dattée et al. (2017), on ecosystem actors committing to activity based on their anticipations of value capture. In addition, the combination of the technological perspective and the exploration of the cognitive domain provide evidence on the implications of emerging technologies in motivating organizations to engage in self-disruptive activities (Ansari et al. 2016). Furthermore, the results present insight on connecting the implications of emerging technologies with the re-configuration and expansion of the range of available resources in organizations, and the needs that may be addressed (Amit & Han, 2017). Indeed, technologies that disrupt the transformation processes executed within the domain of interest, enable novel resource configurations, but also create new needs by fulfilling the old ones. For example, along the enablement of electric mobility, new needs emerge for seamless operability in terms of charging solutions.

Even though Dattée et al. (2017) note that generative technologies that present an unbounded range for potential applications, create restrictions and challenges for sensemaking processes and guidance of ecosystem development, this study has indicated that a combination of a strong value proposition, radical innovation, and generative potential is a significant source of hype establishment. The hype itself has an element of mythology, as viral interest towards a technology is established through a perception of an attractive value proposition, while the actual applicability and functionality of the technology remains as rather ambiguous. Yet, such development may positively contribute with ecosystem emergence, as temporally aligned strong expectations and motivation stimulate activities across industries, empowering creative institutional work for overcoming the barriers of ecosystem development required for addressing the expanding range of needs. By leveraging the hype-momentum, the ambiguity of an emerging technology may become contained and clarified through institutional work that establishes beachheads and rules for the new technology within the dominant socio-technical regime. These findings support the contemporary research according to which convergence of shared cognition and activity around a technology may trigger events for ecosystem emergence, thus providing a lens for describing and predicting technological transitions (Almpanopoulou et al. 2017; Bergman et al. 2017).

This thesis has developed a framework for analysing emerging technologies within their surrounding environments, establishing a link between various streams of academic literature such as technology, innovation, ecosystems, and managerial cognition. The proposed framework further contributes to developing knowledge and understanding on systemic transformations, that are widely identified as complex non-linear processes (Geels, 2002; Adner & Kapoor, 2015; Ansari et al. 2016; Aarikka-Stenroos & Ritala, 2017; Dattée et al. 2017). Indeed, high contextual correlation between the components of the framework canvas were identified through a qualitative case study. Within multiple observations, the component domains appeared as highly overlapping. This suggests that ecosystems develop through an intrinsic interplay and re-configuration between motivation, expectations, temporality, shared cognition and dominant logic, and the on-going technological transition trajectories, that are embedded in their surrounding environments, consisting of actors, technologies and institutions.

7.2. Practical and policy implications

This thesis has presented an analysis model for dealing with uncertainty related to emerging technologies and innovations. The theoretical framework canvas explicitly provides boundaries for exploring the implications of emerging technologies in systemic development trajectories. Moreover, the general findings of this study may be elaborated through the previously specified research questions, which provide further detail to the implications for the results of this study. Overall, due to its unique positioning under pressure for a profound systemic change, the Finnish energy sector provided an interesting research context, whereas the blockchain technology was identified as an emerging technology with a potent and disruptive value proposition. By analysing a multifaceted collection of research data, this study has revealed multiple considerations for business managers and technology developers in the energy industry.

- *What are the implications of the blockchain technology in the development of the Finnish energy sector?*

The blockchain is a generative technology that creates re-configurative implications in the Finnish energy sector by enabling the full-scale utilization of the developing IoT layer of business. More specifically, this refers to the emerging smart grids that consist of not only a myriad of product and service providers, and end-users, but also of distributed autonomous end-point devices such as AMR meters, battery units, and electric vehicles. The objective of such IoT layer is to digitize the physical business processes and simplify the business workflows of organizations, eventually resulting in a growth of revenue through cost reduction enabled by full transparency between core business processes and interaction between a myriad of legal entities and systems. In order to achieve such state, an integration layer such as the blockchain is needed for scaling services for end customers through integration with other counterparties that deliver complementarities. In such environment, where different stakeholders operate as value co-creators, a need for a neutral ground between organizations emerges. Such neutrality may be achieved by implementing blockchain systems, that natively facilitate trust, security, and automation between the network participants. Through the emergence of a ubiquitous integration layer, the full potential of AI technologies capable of cognitive processes, becomes available. Such technologies that produce outputs that have previously required human interaction, enable new ways of organizing and allocation of resources to increasingly value-adding activities. Hence, the blockchain may be considered as an essential component in the technological transition of the energy sector towards self-learning and self-improving systems, which are ultimately required to achieve a state of completely renewable and clean energy system.

The blockchain proposes a fundamental change to the system architectures of the Finnish energy sector. While the contemporary energy ecosystem is built on centralized systems and infrastructure, the blockchain technology introduces a potent value proposition of complete decentralization. Hence, the blockchain may create implications in the development of the energy sector, by re-arranging the roles of the ecosystem actors and democratizing value-creation opportunities. For example, in case bypassing the physical infrastructure of the DSO becomes plausible due to digital technologies and services, such as P2P electricity trading, the DSOs must eventually transition from static and linear collaborators into dynamic and interactive transaction enablers, that provide complementary services (i.e. bandwidth or data processing) to the transaction processes executed within the energy ecosystem. This reflects on a significant change on how the energy ecosystem is arranged.

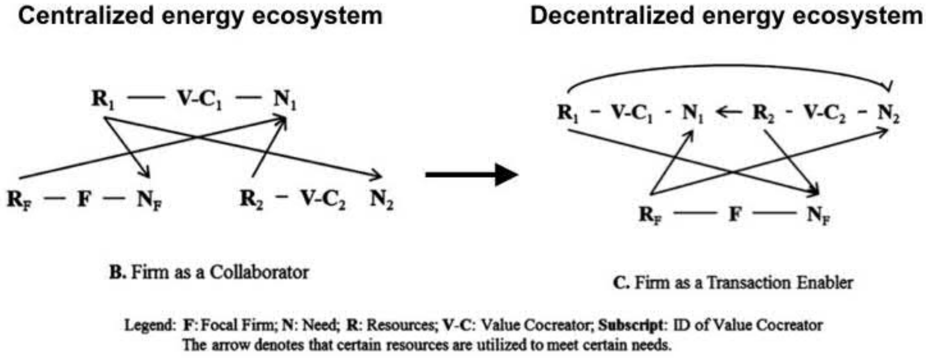

Figure 27. Transformation of the Finnish energy ecosystem (adapted from Amit & Han, 2017)

The value proposition of the blockchain technology entails a reversal of the resource configuration of the energy sector. Figure 27 illustrates how the needs of the market actors may be addressed through an increasing number of resources, as transaction between the previously detached ecosystem sides becomes plausible due to the emergence of transaction enablers. The configuration C is essentially the same as configuration B, but simply put the other way around. The main difference is that the decentralized system structure combined with technologies that natively facilitate and enable such complex interaction, expands the organizational fields of the ecosystem structure, and enable creation of novel co-value propositions. Such development creates new requirements for incumbent organizations to review their own ecosystem positioning in terms of core value proposition and resource configuration. Along the developing decentralization of the energy sector, understanding the expanding range of available resources, possessed by new market entrants or incumbent competitors, that may be utilized in addressing either the existing, or the expanding range of needs, becomes paramount. Yet, the implications of the blockchain technology in the development of the Finnish energy sector are dependent on the actual implementations. Hence, exploration of the defined sub-research questions of this study is essential.

- *How the blockchain technology can be applied in the energy secto*r?

- *What are the challenges for adopting the blockchain technology in the energy sector?*

The use-cases presented in the chapter five provide an overview on the applicability of the blockchain in the energy sector. Bilateral electricity trading, and electric vehicle roaming were provided as examples. As discussed in this thesis, the blockchain is fundamentally a management technology for immutable decentralized data that enhances automation and information security and trust in complex networks of systems and actors. Security and trust is essentially enabled by the blockchain protocol consisting of cryptography, consensus mechanism, and tokens, while the application layer such as smart contracts enable automation. Hence, the blockchain is a potent technology for facilitating seamless and effortless micro-transactions between multiple parties. For example, in the case of electricity, as the tokens utilized in the blockchain can be effectively divided into small fractions, purchasing and selling cheap electricity in small and intermittent, but continuous streams, becomes possible. This can be further illustrated through the EV-roaming example, where an electric vehicle may connect to a charger only for few seconds during the time spent idle in traffic lights. The quantity may be small during a single transaction, but the process may be seamlessly continued at the next stop-over, eliminating the need for long charging cycles.

Yet, the implementations of the blockchain applications in the Finnish energy sector do not come without challenges. Misalignment may be observed between the functionality of the blockchain technology and the actors, technologies, and institutional environment of the Finnish energy sector. Indeed, the energy sector incorporates highly monopolistic features, whereas the blockchain represents an open and democratic approach to market arrangements. Hence, the blockchain technology as such is not compatible with the dominant socio-technical regime. Also, as previously discussed, the energy sector incorporates natural inertia against digitalization and technological transitions due to long investment cycles and highly institutionalized decision making. Further issues emerge from the regulatory environment. For example, before any kind of transactive energy services may succeed in gaining momentum and participants, the contemporary taxation scheme needs to be updated to support the fast pace of technological development and interaction in the energy sector. Furthermore, in the absence of standardization and regulation, multiple security, trust, and legal issues hinder the adoption and usage of immutable smart contracts and transactions across blockchain fabrics.

As of today, the blockchain technology suffers from high level of ambiguity in terms of applicability and technical capabilities. Indeed, further technological development and common grounds need to be established in order to enable actual production grade blockchain deployments. Especially in the early stages of development, it is essential to ensure that the participants of the blockchain ecosystem “speak the same language”. Generally accepted evaluation and management frameworks for the blockchain technology development are yet to be established.

7.3. Limitations and future directions

Of course, this study does not come without limitations. Importantly, the empirical research presented in this thesis is conducted as a single-case-study. Further academic inquiries and multiple-case studies are required in order to validate the applicability of the proposed framework and findings. Consequently, this study can be considered as a pilot case for enabling future inquiries on the innovation in focus. What is more, the case study is conducted in Finland. Thus, the results cannot be applied without consideration to international markets, as the energy ecosystem is geographically limited. It is important to acknowledge that regional energy ecosystems around the world are associated with divergent characteristics.

The development of the blockchain technology is currently at its early stages. Thus, it may be argued that no clear and definitive implications can be observed in the Finnish energy sector. Indeed, the research context is considered as immature, while the results are somewhat speculative. However, one of the objectives of this study was to specifically collect data during such temporal opening, as corresponding research typically addresses industry transformations only after a disruption has occurred. Such approach enabled a more precise focus on the cognitive aspect of technological transitions, and how the emerging technologies interact with their surrounding environments. In addition, one of the challenges that emerged during the research process, was the overall lack of expertize available in the specific field of energy sector and the blockchain technology. This is mostly explained by the fact that no actual production grade blockchain deployments have been made within the Finnish energy sector context at the time of conducting this study. Even though good saturation was achieved for the research data, the future research is encouraged to carefully evaluate the data sources and seek out for a larger sample within the specified scope.

This study has presented insights on the implications of the blockchain technology in the development of the Finnish energy sector based on a cross-sectional analysis, referring to consideration of the phenomenon of interest in a specific contemporary time (Saunders et al. 2009). In this sense, this study represents an early inquiry on the phenomenon of interest that calls out for longitudinal research in the future to validate and revise the initial findings. As for future studies, in order to validate the applicability of the proposed framework canvas, it would be interesting to replicate the study in 5-10 years, after which the blockchain is expected to reach its technological maturity. The results could reveal whether the proposed canvas components managed to capture the determinants of the implications of an emerging technology in a systemic transformation.

Furthermore, this study has indicated the re-configurative potential of the blockchain technology in industry structures and roles. Yet, a need for developing better evaluation frameworks for blockchain implementations in different industries has been identified. Hence, a contemporary approach on studying the blockchain and technological transitions should aim to provide further micro-level detail on *how* the blockchain is re-configuring the resources and needs of specific ecosystem actors. Finally, as the blockchain technology itself is a novel field for research, further analysis by utilizing different perspectives on the technology and its usage, is highly encouraged. For example, one could adopt a game-theoretic view on simulating how the stakeholders of an energy community engage in P2P-transactions within a blockchain-enabled transactive micro-grid. Such simulation could be conducted by first considering the micro-grid as a closed and self-sufficient environment, after which real-time market data on available supply and demand could be taken into consideration. Such approach could reveal important insights on energy system optimization.

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Appendix 1

Expert interview guide.

Background information

- Could you tell me shortly about yourself? (position and responsibilities)
- In your own words, how would you assess your knowledge and experience on the blockchain technology and the energy sector?

General situation of the energy sector

- How do you see the current situation of the Finnish energy sector? What kind of development trends are perceptible? (i.e. digitalization, culture, norms, economics, policy, infrastructure)
- Where do you see the opportunities for innovation, new services and business development in general?
- Do you see any threats or plausible sudden events that might significantly impact the development of the energy sector, either negatively or positively?

Blockchain as a disruptive innovation

- What kind of a role do you think the blockchain technology has in the development and renewal of the energy sector during the next 5-10 years? Do you consider this as disruptive?
- To what kind of “problems” does this innovation provide solutions to? What kind of vision and added value proposition does it provide?
- Who are the industry stakeholders that are being disrupted by this innovation/technology? How are they being disrupted?
- Can you identify any essential complementary technologies for this innovation?

Development

- In the context of the Finnish energy sector, could you identify the key organizations that are actively developing this innovation/technology?
- How would you describe the maturity, level of knowledge, and improvement potential of this innovation/technology?
- Are there any development trends or dominant designs forming around this innovation/technology? (i.e. standardization, platforms)
- What would you consider as the most significant challenges or institutional barriers for the development of this innovation/technology?

Support, collaboration and adoption

- Can you identify the key stakeholders and industry incumbents whose support is essential for building critical mass and acceptance for this innovation?
- Can you describe the collaboration and relationships between the developers of this innovation and these key stakeholders and incumbents?
- Do you see conflicting interests between these parties you have identified? (developers and incumbents)
- In your opinion, what is the key in building a shared vision among these energy ecosystem stakeholders for capturing the added value creation potential of the blockchain technology?

To conclude:

- What are your expectations regarding the development/future of the energy sector and the innovation/technology discussed, in the next 5-10 years?
- Thinking back over our discussion, is there anything else of importance you'd like to add or anything that we didn't talk about that appears relevant?

Appendix 2

Questionnaire 1: Blockchain technology - Expectations on energy sector applications

1. My current organization

____

2. How familiar are you with the business and/or technical context of the energy sector in general?

1 2 3 4 5

No experience ◯ ◯ ◯ ◯ ◯ Expert

3. How familiar are you with the blockchain technology in general?

1 2 3 4 5

No experience ◯ ◯ ◯ ◯ ◯ Expert

4. Blockchain is an important technology in the renewable energy sector transformation.

1 2 3 4 5

Strongly disagree ◯ ◯ ◯ ◯ ◯ Strongly agree

5. During the next 5-10 years, I expect the blockchain technology to cause major changes in the way we produce and consume energy.

1 2 3 4 5

Strongly disagree ◯ ◯ ◯ ◯ ◯ Strongly agree

6. Meeting these expectations is realistic and extremely probable.

1 2 3 4 5

Strongly disagree ◯ ◯ ◯ ◯ ◯ Strongly agree

7. What will be the most important blockchain-enabled energy application during the next 5-10 years?

____

____

Appendix 3

Questionnaire 2: Blockchain technology / Energy sector word association exercise

1. On a scale from 1-5, how familiar are you with the business and/or technical context of the Finnish energy sector in general?

1 2 3 4 5

Low ◯ ◯ ◯ ◯ ◯ High

2. On a scale from 1-5, how familiar are you with the blockchain technology in general?

1 2 3 4 5

Low ◯ ◯ ◯ ◯ ◯ High

3. Please enter 5-10 words that first come to your mind when thinking of the current core technologies of the energy sector.

1. ______________________________ 2. ______________________________
3. ______________________________ 4. ______________________________
5. ______________________________ 6. ______________________________
7. ______________________________ 8. ______________________________
9. ______________________________ 10. ______________________________

4. Please enter 5-10 words that first come to your mind when thinking of how the blockchain technology can be applied and adopted in the energy sector.

1. ______________________________ 2. ______________________________
3. ______________________________ 4. ______________________________
5. ______________________________ 6. ______________________________
7. ______________________________ 8. ______________________________
9. ______________________________ 10. ______________________________

Appendix 4

Development process of the SNA exercise conducted in this study (figure 22)

All secondary interview transcriptions were merged to a single text file and processed with find and replace functions to create a ***uniform string of text*** with delimiters removed and all individual words separated with spaces. Replacing all spaces with line breaks resulted in total 122 104 words ***in their original order of appearance***, one word per row. The results were then copied into Excel for further analysis.

Keeping the original order, all ***"and" –words, articles, numbers and dates were removed*** resulting in 106 705 words. The frequency of each word was counted with COUNTIF -function, and the sheet was locked as the ***baseline*** of analysis. All words with ***frequency lower than 10*** were considered irrelevant and were ***removed***. In order to create a list of *key words*, the previous stage was copied to a new sheet and sorted first ascending based on the name, and then descending based on word frequency. ***Duplicates were removed***, resulting in 5 058 unique words and their frequencies. The list was then ***qualitatively filtered*** to keep only relevant, "energy sector" -related words. This filtering resulted in a list of 247 unique words, constituting the final list of *key words* and their frequencies.

The objective of the analysis was to uncover the ***structural relations*** between individual ***key words***, representing the domains of the energy sector. Thus, a new column was added to the ***baseline*** sheet indicating the ***next word from the original***. The filtered ***key words*** were referenced against the ***baseline*** string of text with a VLOOKUP –function. If both ***original***, and the ***next word*** were present in the ***key word*** list, the words were ***merged*** into pairs, sorted, and their frequencies calculated. Then, ***duplicates were removed***. As the merging process was ***based on the original order of word appearance***, the pairs of ***key words are co-related*** in the discourse context of the energy ecosystem.

The visualization of the energy ecosystem was created in ***Gephi 0.9.1***, by adjusting the node weight as the frequency of the individual ***key word***, while the edge weight represents the ***frequency*** of the combined words. The node ***"energy"*** was removed due to its highly dominant position and weight. The final ecosystem layout was achieved by running ***OpenOrd*** algorithm on the dataset with Gephi default settings, aiming to highlight clusters. This algorithm is originally based on Fruchterman-Reingold which optimizes distance the between nodes so that nodes with strong connections pull on each other, whereas those who are distant will push one another apart (Basole, 2009). In addition, ***NoOverlap*** algorithm was applied with a ratio of 3,5 to distinguish the labels from each other. The graph was colour coded based on ***closeness centrality***, ranging from values 0,27 (red) to 0,54 (blue). Closeness centrality overcomes the deficiency of in-degree measure by emphasizing the nearness of a node to all others in the network by using the reciprocal of the geodesic distances, thus describing the network as a whole (Basole, 2009).